PB-245 615

WATER POLLUTION INVESTIGATION: LOWER GREEN BAY AND LOWER FOX RIVER

D. J. Patterson, et al

Wisconsin Department of Natural Resources

Prepared for:

Environmental Protection Agency

June 1975

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EPA/905/9-74/017

WATER POLLUTION INVESTIGATION: LOWER GREEN BAY AND LOWER FOX RIVER

WISCONSIN DEPARTMENT OF NATURAL RESOURCES

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION V ENFORCEMENT DIVISION
GREAT LAKES INITIATIVE CONTRACT PROGRAM

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JUNE 1975

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/905/9-74/017	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Water Pollution Investigation: Lower Green Bay and Lower Fox River		5. REPORT DATE June 1975 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) D. J. Patterson, E. Epstein, and J. McEvoy		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Wisconsin Department of Natural Resources Division of Environmental Standards Box 450 Madison, Wisconsin 53701		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. EPA No. 68-01-1572
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Enforcement Division, Region V 230 S. Dearborn Street Chicago, Illinois 60604		13. TYPE OF REPORT AND PERIOD COVERED Final Report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

EPA Project Officer: Howard Zar

16. ABSTRACT

The lower third of Green Bay and the Lower Fox River were intensively studied. Seven surveys of the Bay were carried out between September 1973 and September 1974. Over 40 stations were sampled for 15 different chemical and physical parameters. In addition, plankton samples were taken and general groupings and counts were made. Nearly 5,000 data points were generated and inserted into the STORET system. The surveys revealed algae blooms over the entire study area. Nitrogen forms showed fluctuations over 3 orders of magnitude that may be relatable to nitrogen-fixing algae. Phosphorus concentrations were more stable than nitrogen concentrations, but appeared to decrease in correspondence to blue-green nitrogen-fixing algae. Dissolved oxygen concentrations in the Bay were generally acceptable except during the winter survey. The February survey revealed critical dissolved oxygen levels over a 50 sq. mile area north of Point Sable.

Computer models of the Lower Fox River and Green Bay were developed and used to evaluate the effect of the final limits for the present discharge permits at all point source discharges on the water quality, specifically dissolved oxygen. The most critical dissolved oxygen case was determined by the model to be the summer low flow and high temperature condition in the river. The final discharge limits from the present permits was shown to be inadequate to meet fish and aquatic life standards with regard to dissolved oxygen (5 mg/l) and may even violate the variance dissolved oxygen standards now in force. A proposed "waste load allocation" to maintain 5 mg/l of DO was developed. The WLA calls for a 37% decrease in BOD and suspended solids from the final discharge levels on the present permits.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water Quality Aquatic Biology Water Pollution 1.	Green Bay Lake Michigan Great Lakes Fox River Chemical Parameters Biological Parameters	

18. DISTRIBUTION STATEMENT Limited number of copies from U.S. EPA, Chicago. At cost of publication from NTIS, 5285 Port Royal Rd., Springfield, VA 22161	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES 376
	20. SECURITY CLASS *(This page)*	22. PRICE 10.25-2.25

☆U.S. Government Printing Office: 1975 — 650-478/1101 Region 5-1

PRICES SUBJECT TO CHANGE

WATER POLLUTION INVESTIGATION: LOWER GREEN BAY AND LOWER FOX RIVER

by

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WISCONSIN DEPARTMENT OF NATURAL RESOURCES

DIVISION OF ENVIRONMENTAL STANDARDS

In fulfillment of

EPA Contract No. 68-01-1572

for the

U.S. ENVIRONMENTAL PROTECTION AGENCY
Region V
Chicago, Illinois 60604

Great Lakes Initiative Contract Program
Report Number: EPA-905/9-74-017

EPA Project Officer: Howard Zar

June 1975

This report has been developed under auspices of the Great Lakes Initiative Contract Program. The purpose of the Program is to obtain additional data regarding the present nature and trends in water quality, aquatic life, and waste loadings in areas of the Great Lakes with the worst water pollution problems. The data thus obtained is being used to assist in the development of waste discharge permits under provisions of the Federal Water Pollution Control Act Amendments of 1972 and in meeting commitments under the Great Lakes Water Quality Agreement between the U.S. and Canada for accelerated effort to abate and control water pollution in the Great Lakes.

This report has been reviewed by the Enforcement Division, Region V, Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

The authors of this report wish to thank the many people who contributed their time and energies to the completion of this project. In particular, Steve Jaeger and Marc Bryans spent many long hours assembling the data from past reports and present surveys, Joe Ball headed the field work operations, James Wiersma (University of Wisconsin-Green Bay) supervised the water chemistry analysis and finally, Kwang Lee (University of Wisconsin-Green Bay) developed the hydrodynamic model that made the development of the Green Bay water quality model possible.

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ABSTRACT

The lower third of Green Bay and the Lower Fox River were intensively studied. Seven surveys of the Bay were carried out between September 1973 and September 1974. Over 40 stations were sampled for 15 different chemical and physical parameters. In addition, plankton samples were taken and general groupings and counts were made. Nearly 5,000 data points were generated and inserted into the STORET system. The surveys revealed algae blooms over the entire study area. Nitrogen forms showed fluctuations over 3 orders of magnitude that may be relatable to nitrogen-fixing algae. Phosphorus concentrations were more stable than nitrogen concentrations, but appeared to decrease in correspondence to blue-green nitrogen-fixing algae. Dissolved oxygen concentrations in the Bay were generally acceptable except during the winter survey. The February survey revealed critical dissolved oxygen levels over a 50 sq. mile area north of Point Sable.

Computer models of the Lower Fox River and Green Bay were developed and used to evaluate the effect of the final limits for the present discharge permits at all point source discharges on the water quality, specifically dissolved oxygen. The most critical dissolved oxygen case was determined by the model to be the summer low flow and high temperature condition in the river. The final discharge limits from the present permits was shown to be inadequate to meet fish and aquatic life standards with regard to dissolved oxygen (5 mg/l) and may even violate the variance dissolved oxygen standards now in force. A proposed "waste load allocation" to maintain 5 mg/l of DO was developed. The WLA calls for a 37% decrease in BOD and suspended solids from the final discharge levels on the present permits.

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SECTION I

I. INTRODUCTION

Green Bay is a long, narrow bay in the northwest corner of Lake Michigan. It has a length of about 120 miles and averages about 20 miles in width. The Bay extends over a generally southwest to northeast axis. Several rivers flow into the Bay from the west and south, none from the east. Figures I-1 and I-2 show Green Bay and its setting.

The most important tributary to Green Bay is the Lower Fox River, which enters at the extreme southern end of the Bay. The Lower Fox River is approximately 40 miles long. Several dams subdivide the river into a series of segments and provide electrical power for a large population and a heavy concentration of paper and pulp mills. The Lower Fox River provides a source of municipal and industrial waste which results in pollution problems over a large area of Lower Green Bay. Locally intense but smaller areas of pollution occur at the mouth of the Oconto, Peshtigo and Menominee Rivers.

The water pollution in the Lower Fox River and Green Bay region has caused the U.S. Environmental Protection Agency (EPA) and the Wisconsin Department of Natural Resources (WDNR) to initiate a series of enforcement actions which involve industrial and municipal waste discharges in the area. Also, the 1972 Amendments to the Federal Water Pollution Control Act (Public Law 92-500) require that municipalities shall provide, as a minimum, secondary treatment, and industries shall achieve "Best Practicable Technology" (BPT) by no later than 1977. The law also requires that the industries shall use "Best Available Technology" (BAT) to control water pollution by 1983.

FIGURE I-1

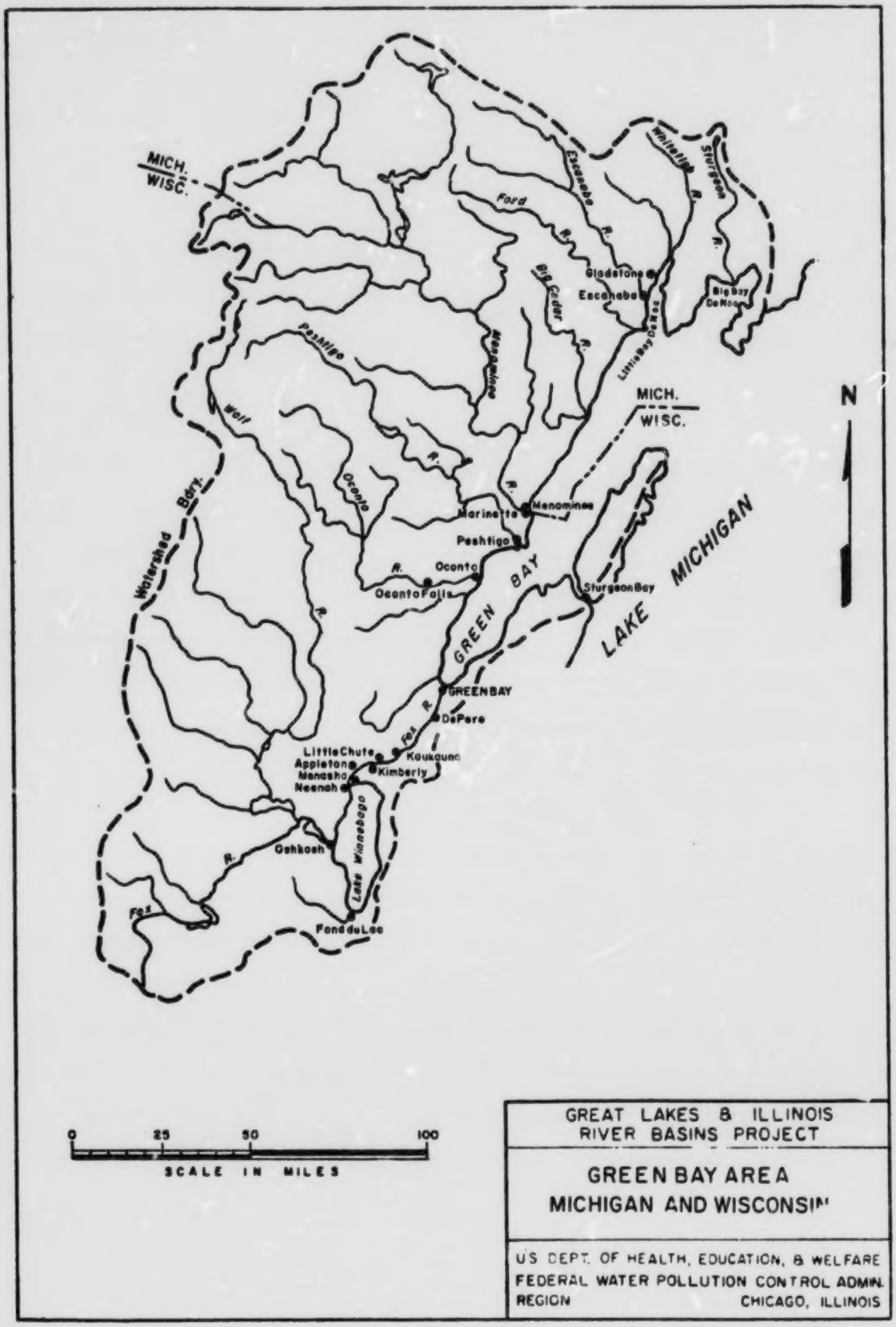
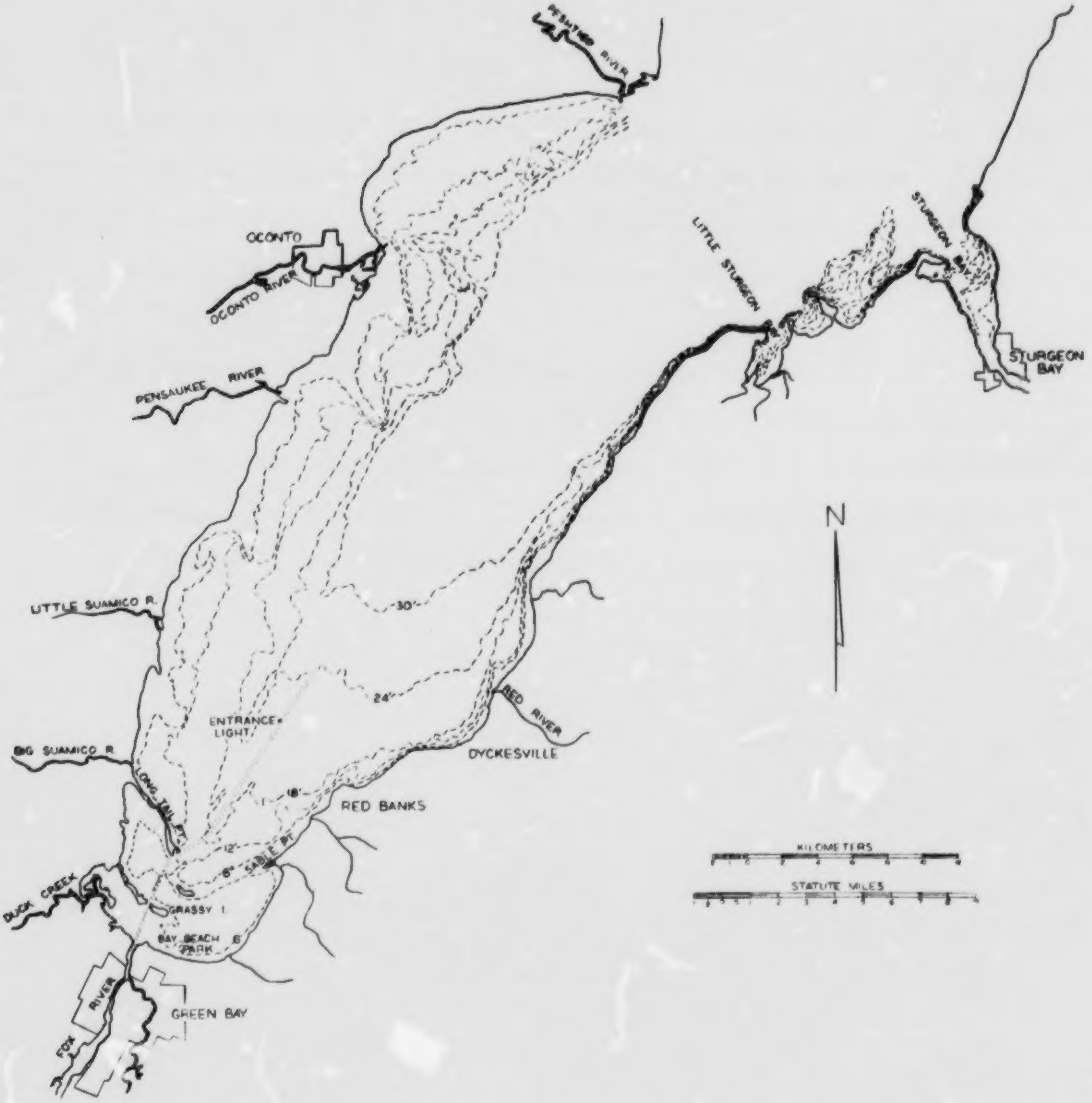

MICH.
WISC.
Escanaba R.
Whitefish R.
Sturgeon R.
Ford R.
Big Cedar R.
Gladstone
Escanaba
Big Bay De Noc
Little Bay De Noc
Menominee R.
Peshtigo R.
Wolf R.
Oconto R.
Watershed Bdry.
MICH.
WISC.
N
Menominee
Marinette
Peshtigo
Oconto
Oconto Falls
GREEN BAY
Sturgeon Bay
LAKE MICHIGAN
GREENBAY
Fox R.
DePere
Little Chute
Appleton
Menasha
Neenah
Kaukauna
Kimberly
Oshkosh
Lake Winnebago
Fond du Lac
Fox R.
0
25
50
100
SCALE IN MILES
GREAT LAKES & ILLINOIS RIVER BASINS PROJECT
GREEN BAY AREA
MICHIGAN AND WISCONSIN
US DEPT. OF HEALTH, EDUCATION, & WELFARE
FEDERAL WATER POLLUTION CONTROL ADMIN.
REGION
CHICAGO, ILLINOIS

FIGURE I-2


PESHTIGO RIVER
OCONTO
OCONTO RIVER
PENSAUKEE RIVER
LITTLE STURGEON
STURGEON BAY
STURGEON BAY
N
LITTLE SUAMICO R.
30'
24'
ENTRANCE LIGHT
RED RIVER
DYCKESVILLE
BIG SUAMICO R.
LONG TAIL PT.
18'
RED BANKS
12'
6'
SABLE PT.
KILOMETERS
STATUTE MILES
DUCK CREEK
GRASSY I.
BAY BEACH PARK
FOX RIVER
GREEN BAY

Municipal waste treatment plants must apply BPT over the life of the treatment works by 1983. New public waste treatment plants must use the best available technology after 1983. The Amendments also require that system water quality standards must be met.

The purpose of this work was to conduct a survey of the Lower Fox River and of Lower Green Bay. Emphasis was placed on those parameters which describe the quality of the water. In addition, a goal of the work was to predict future water quality conditions by means of a mathematical model adapted to the Lower Fox River and to the Bay.

The scope of the study is discussed in Section II. The results of past studies and of the data collected in this study which constitute the data base for Green Bay are presented in Section III. The data analysis and projection which constitutes the water quality modelling appear in Section IV. A discussion of the results appears in Section V. Recommendations appear in Section VI. References are listed in Section VII. Appendices appear in Section VIII.

SECTION II

II. SCOPE OF THE STUDY

Task I - Historical Data Analysis: An evaluation of the existing and historical conditions in Lower Green Bay was carried out and the results published in August 1974 (Epstein et al, 1974). This information was contained in the reports of studies carried out intermittently between 1939 and 1973. In addition the report lists the sources and quantity of waste discharge to Green Bay from municipalities and industries along the Lower Fox, Peshtigo, Oconto and Menominee Rivers.

Task II - Field Sampling: A sampling program was designed to improve the adequacy of the water quality data for Lower Green Bay and to provide sets of data for verification of the mathematical model. Seven surveys were conducted over the period September 1973 to September 1974 in the region below Sturgeon Bay. One intensive survey was conducted in February of 1974 when the Bay was ice-covered, a condition which has led to critical oxygen levels in parts of the region below Sturgeon Bay.

Task III - Effluent Analysis: The Lower Fox, Oconto, Peshtigo and Menominee Rivers are the major tributaries to Lower Green Bay. The flow rates and concentrations of various dissolved and suspended materials for these rivers indicate that, as a quantitative source of pollution, the Lower Fox River exceeds the other rivers by nearly an order of magnitude. The sources and quantity of both municipal and industrial discharge to these rivers are presented in the Task I report, Epstein et al (1974). These data include projections of the waste loadings by industries of suspended solids and of five-day biochemical oxygen demand (BOD_5) to the various rivers for the years 1975, 1976 and 1977. These projections are based on the amounts specified in the Wisconsin Pollution Discharge Elimination (WPDES) permits for these industries.

Task IV - Data Analysis and Projection: A description of present water quality, a projection of future conditions and a specification of problem areas has been made. A water quality model has been prepared for the Lower Fox River and for Lower Green Bay based in part on models developed for the coastal estuaries of San Francisco Bay and Pearl Harbor and partly on programs developed specifically for this task. This package of programs is the principal tool for the projections of water quality that would result if effluent guidelines established by the EPA administrator under Sections 301(b)(1)A, 301(b)(1)B, 301(b)(2)A and 301(b)(2)B of the 1972 Amendments to the Federal Water Pollution Control Act are met. If stream standards are not met by adherence to the provisions of the law, then calculations are to be made of those effluent levels which will suffice for the "protection of fish, shellfish and wildlife and provide for recreation in or on the water."

SECTION III

III. THE DATA BASE FOR GREEN BAY

Task I - Historical Data Analysis: Extensive investigations of Green Bay have been carried out intermittently since 1939. A major emphasis in many of these investigations has been on measurements of the concentration of dissolved oxygen (DO) and biochemical oxygen demand (BOD). Measurements of the concentrations of various nutrients (nitrogen and phosphorus containing species) have also been a significant part of several of these investigations. However, the effects of these nutrients on the growth of algae and other species have only recently been a subject of intensive investigations. The Sea Grant program at the University of Wisconsin has generated several studies on Green Bay in recent years. A summary of the results of the Green Bay surveys appear in the Task I report, Epstein et al (1974). Reference to this report will be made for the purpose of qualitative comparisons with the results of this investigation.

The following are the major subjects of extensive study in past surveys:

Dissolved Oxygen and Biochemical Oxygen Demand: The concentrations of these species were measured extensively throughout Lower Green Bay in 1939, 1956, 1966 and 1967. The concentration of dissolved oxygen was generally lower for the period when the Bay was ice-covered. The same general pattern of dissolved oxygen concentration was observed throughout this period.

During the period of ice-cover (the months of January, February, March and part of April), water in the Lower Fox River generally was found to have a dissolved oxygen concentration greater than 5 mg/l. However, a front of low oxygen concentration develops in the Bay within Long Tail Point. This front moves northward along the eastern half of Lower Green Bay for distances of 20-30 miles by the end of the period of ice-cover. In 1939, concentrations of dissolved oxygen dropped to values of 3-4 mg/l in the front. In 1967, no dissolved oxygen was observed near the bottom of the Bay for a wide portion of the front. Conditions are less severe during the period of open water due to reaeration. During the late summer the Lower Fox River has very low or no dissolved oxygen. However, oxygen recovery in the Bay is rapid, especially north of Long Tail Point.

Biochemical oxygen demand (BOD) has been measured less extensively and intensively than dissolved oxygen. As a result, it is not possible to make a generalization about the pattern of BOD concentrations over the past 35 years. However, sufficient data exists to show that loadings of BOD to the Lower Fox River have not changed significantly when compared with those of 20 years ago. This is due to improved treatment by municipalities and industries offsetting a significant increase in population and industrial production.

Nutrients: The change in concentrations of nutrients (nitrogen and phosphorus containing species) over the past 35 years is difficult to determine because data from earlier years is spotty or lacking entirely. The concentration of nitrogen and phosphorus containing species in Lower Green Bay has been a subject of considerable interest in the last few years. In addition to concentration, the dispersal and diffusion, the release and uptake rates by the sediments and the effect on algae growth rates of these species have been investigated in Lower Green Bay in past studies.

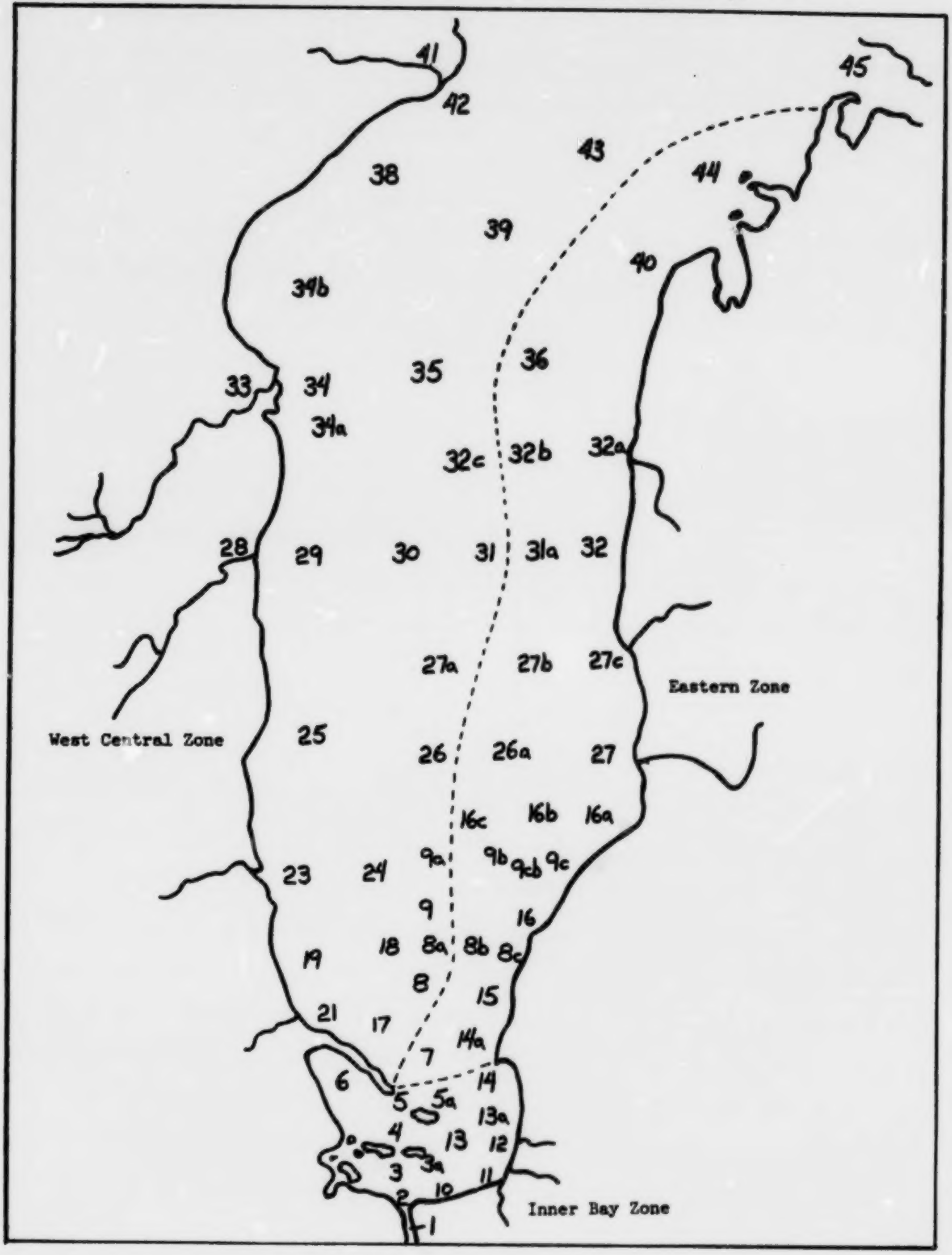
Flow Distribution: The flow patterns in Green Bay have not been investigated directly. Historically, qualitative descriptions of flow patterns have been based on observations of oxygen concentrations or on the concentration gradients of other ions.

Benthic Fauna: Several studies since 1939 have measured the populations of bottom dwelling species. These studies show an increasingly large abiotic area near the mouth of the Lower Fox River. Throughout the Lower Bay the population of pollution intolerant species has fallen in relation to pollution tolerant species in the last twenty years.

Algae Growth: The response of the Bay to the various nutrients has been a subject of considerable study in recent years. For the period before about 1968, data is limited. Recent investigations have indicated that the total algae population may be about the same each summer but that the distribution may vary widely from year to year.

Task II-Field Sampling: The sampling program included surveys in September 1973, February, May, June, July, August and September 1974. Nearly seventy station sites were designated in that portion of Green Bay below Sturgeon Bay. Not all of the stations were visited in the winter survey (February 1974) and not all parameters were measured in each survey. Several extra sites were visited to measure DO during the winter survey. The sampling schedule was designed to provide data from a variety of temperature, flow and nutrient discharge conditions. The selections of sites and of the parameters to be measured in a particular survey were based on an analysis of the results of earlier surveys and the requirements and capabilities of the mathematical model. The station sites and the parameters measured at these sites are shown in Figure III-1 and Table III-1.

FIGURE III-1
Sampling Stations Used for the Green Bay Study Surveys



41
45
42
43
38
44
39
40
34b
36
35
33
34
34a
32c
32b
32a
28
29
30
31
31a
32
27a
27b
27c
Eastern Zone
West Central Zone
25
26
26a
27
16c
16b
16a
9a
9b
9cb
9c
23
24
9
16
19
18
8a
8b
8c
8
15
21
17
14a
7
6
14
5
5a
13a
4
13
12
3a
3
11
2
10
1
Inner Bay Zone

TABLE III-1

Station	Winter*	Summer*
1	b	b
2	a	b
3	b	a
3a	a	x
4	b	b
5	a	a
5a	b	x
6	b	b
7	b	b
8	b	a
8a	a	x
8b	b	x
8c	a	b
9	b	a
9a	a	x
9b	b	b
9c	a	x
10	b	a
11	a	a
12	b	b
13	b	b
13a	b	a
14	a	b
14a	b	x
15	a	a
16	b	a
16a	b	a
16b	a	x
16c	b	x
17	x	b
18	a	c
19	x	a
21	x	a
23	x	a
24	b	b
25	b	a
26	a	c
26a	a	x
27	a	b
27a	b	x
27b	a	x
27c	b	x
28	x	c
29	x	c
30	b	a
31	a	b
31a	b	x
32	a	a
32a	a	x
32b	a	x
32c	a	x
33	b	c
34	b	a
34a	b	a
34b	b	x
35	x	b
36	b	a
38	a	c
39	x	a
40	a	c
41	b	c
42	x	a
43	b	b
44	x	a
45	b	b

a DO; temperature; secchi disk

b DO; temperature; secchi disk, plankton samples at 1-1/2 meter depth; water samples from the top two meters (if the depth exceeded 25 feet, then a water sample was taken at 5-10 feet from the bottom.

c the same as b except that plankton samples were not taken

x no sample

* The winter survey was taken on February 18-20, 1974. The summer surveys were taken on September 24-25, 1973, May 20-23, June 3-7, July 8-9, August 12-14, and September 4-5, 1974.

The results of the field sampling program in 1973 and 1974 are summarized in Figures III-2 to III-20. The details of the data obtained and of the techniques employed are presented in Appendices E and F.

Dissolved Oxygen: DO concentrations in the summer are generally above 5 mg/1, through-out the region above Long Tail Point despite the fact that the Lower Fox River may contain little or no dissolved oxygen. These concentrations reflect the rapid oxygen recovery due to reaeration. There are exceptions to this generality. At the end of the summer, when flow rates are relatively low, oxygen concentrations as low as 3 mg/1 were observed near the bottom. The region where these concentrations were observed extended for 20-30 miles north of Long Tail Point. This region coresponds to the maximum northward extension of the front of low DO observed under the ice during the winter months. The low oxygen concentrations near the bottom in summer may reflect a combination of effects. Part of the low DO may be due to the continuing effect of sludge deposits which accumulate at this distance from the mouth of the Lower Fox River.

Indirect evidence also suggests that a substantial oxygen deficit in these areas is the result of nitrification activity. During the July and August surveys the build-up of nitrate in the bottom waters of these areas is most apparent. Levels as high as 1.0 mg/l NO_3-N were measured. This could account for as much as 4.5 mg/l of DO deficit. There are two sources of ammonia for this nitrification. Dead phytoplankton from surface blooms will settle to the bottom bringing along organic nitrogen and carbon compounds. The sediments also contain organic nitrogen compounds. These compounds will undergo hydrolysis which results in the release of ammonia which may nitrify. Support for this theory is found in the nitrate levels which most noticeably increased during the period of highest blue-green algae activity (July and August).

In February 1974, there was a front of low oxygen concentration (about 3 mg/l) near the bottom in the region about 7 miles north of Long Tail Point. This front, its position at the time of year and the low oxygen concentration are generally consistent with observations in other years. Precise comparisons are difficult because the flow rates in the years 1939, 1966, 1967 and 1974 differ from one another by more than 10% and the length of time under ice cover is not the same for all the years. Generally, the BOD loading in 1974 was slightly less than that in 1967 for the Lower Fox River (230,000 #/day versus 275,000 #/day in 1967).

The observed higher flows during the winter of 1974 compared to 1967 creates the expectation of generally higher DO levels in the Inner Bay and a front of low DO further out into the Bay. In 1967 when the average winter flow was 3380. CFS, extensive areas of zero DO were measured. Zero DO was discovered as close to the mouth of the Fox River as Point Sable. In 1974 (average winter flow of 4853 CFS) no zero DO concentrations were observed. The lowest values observed were between 1.5 and 2.0 mg/l in the Dykesville area, nearly 8 miles further north than in 1967.

BOD: The BOD concentration within Lower Green Bay varied considerably with the season of the year. In May and June, when temperatures were still rather cold, concentrations of about 10 mg/l were observed within Long Tail and for some distance beyond. These concentrations then fell rapidly to values of 2-3 mg/l beyond Long Tail Point. Later in the summer, values of about 6 mg/l were observed within Long Tail Point. These values fell rather slowly to 4-5 mg/l near Sturgeon Bay. The concentrations for the spring of 1974 are rather similar to those observed for the same period in 1939. In June of 1955, values as high as 15 mg/l were observed within Long Tail Point.

In February 1974, concentrations of BOD at the mouth of the Lower Fox River were about 6 mg/1. Well beyond Long Tail Point values of about 2 mg/1 were observed. However, at about 10-15 miles beyond Long Tail Point an area of high BOD was observed along the eastern half of the Bay. Values here were as high as 13.5 mg/1 on the bottom and 9 mg/1 on the top. The high BOD corresponded to the position of low dissolved oxygen. In 1939 a similar pattern was observed although the concentrations were higher at the mouth of the river and lower in the region of high BOD beyond Long Tail Point.

The consumption of BOD is dependent primarily on the temperature dependent reaction rates. The observed concentrations of BOD in Green Bay reflect this dependence quite well.

The surveys of May and June 1974 indicate substantial increases in BOD_5 concentration near and slightly beyond the Long Tail Point area. This pattern coupled with a measurement in the Fox River in July that exceeded 30.0 mg/1, suggests the possibility that large slug-loadings of BOD to the river-Bay system occur. This effect could be a physical phenomena resulting from seiche waves in Green Bay that tend to stagnate the river flow from De Pere to the mouth of the river. During the period of stagnation, BOD may build up to high concentrations before being swept out into the Bay by the receding portion of the seiche wave. The high BOD may, of course, come from slug loads from dischargers in the Green Bay area.

The seiche effect in the vicinity of the mouth of the Lower Fox River is important for this regard only when a northeast wind blows large quantities of water back up into the river stretch from De Pere to Green Bay. No attempt was made to include this effect in the Bay model since the hydrodynamics of the model are steady state.

Nitrate: Concentrations of nitrogen as nitrate vary widely with the season of the year. In February 1974 the concentration of nitrate ion was approximately 0.10 mg/l over a wide region of the Inner Bay. This region corresponded closely to the portion of the Inner Bay which had low oxygen concentrations at the same time (the region within Long Tail Point plus the region outside Long Tail Point and along the eastern shore for about 20-30 miles). Beyond this region there where large negative gradients in concentrations of nitrogen as nitrate and background concentrations of 0.01 mg/l and less were observed.

In May, concentrations of nitrogen as nitrate reached values of 0.20-0.40 mg/l in some portions of the region within Long Tail Point. Beyond this point, concentrations fell slowly to values of 0.02 mg/l in areas of the Central Bay. However, concentrations near the bottom were often significantly higher, reaching values of 0.25-0.50 mg/l.

In June, the concentrations of nitrogen as nitrate reached values of 0.7 mg/l at some points within Long Tail Point. Beyond, concentrations fell rapidly to values of 0.05 mg/l or less.

In August, concentrations were significantly reduced when compared with those observed during the period of spring runoff. Within Long Tail Point, concentrations were generally less than 0.10 mg/l. Beyond this point, concentrations fell to values less than 0.03 mg/l. However, near the bottom concentrations in the range 0.7 to 1.0 mg/l were consistently observed. Concentrations in September were not significantly different from those in August. High concentrations near the bottom may reflect the effect of release of nitrogen containing compounds by dead algae. The conversion of these organic nitrogen compounds to nitrate may also account, in part, for the low oxygen concentrations near the bottom. The largest significant increase in nitrate near the bottom corresponds to the period of die-off of the blue-green algae bloom during late June and early July. According to Vanderhoef et al (1972), a large fraction of this nitrate may come from nitrogen fixation.

Ammonia: Concentrations of nitrogen as ammonia were in the range 0.5-0.7 mg/l in February 1974 throughout the region of the Bay where low oxygen was observed. At low temperatures, reduced rates of ammonia decay to nitrite and nitrate cause high concentrations of ammonia. Reduced concentrations of oxygen also contributed to a high ammonia concentration. In the spring, runoff brings large quantities of ammonia. The warmer temperatures and the increased level of oxygen in the Bay cause the concentration of ammonia to fall rapidly as distance from the mouth of the Lower Fox River increases. Ammonia utilization by phytoplankton also contributes to the nearly complete disappearance of ammonia by August.

Phosphorus: The seasonal variation of total phosphorus concentration as phosphorus was less than the corresponding seasonal variation in nitrogen concentration as nitrate. The dramatic rise in nitrogen concentration observed during the spring runoff was not observed for phosphorus. During the spring runoff, the area of the Bay in which the concentration of total phosphorus as P was greater than 0.5 mg/l approximately doubled in size when compared with concentrations in February, but the several-fold increase in concentration observed for nitrate was not observed for the phosphorus species. The seasonal pattern for orthophosphate paralleled that of total phosphorus. The ability of the bottom sediments to hold and release phosphorus containing ions may account for the more stable levels of phosphorus ions over the various seasons. Local fluctuations in time of the concentrations of phosphorus containing ions have been correlated with the bloom of certain blue-green algae. This point will be discussed later.

Total phosphorus concentrations appeared to reach their minimum values during the winter months when quiesent water allows particulate phosphorus to settle to the sediments. Total phosphorus increased between the February and May surveys by about 5-fold. Between the May survey and the June survey the total phosphorus in the Oconto-Sturgeon Bay area nearly tripled. It is doubtful whether this increase can be totally accounted for by spring runoff. A significant amount of phosphorus may be released from sediments that are resuspended by wind and wave action in the shallow areas and along the shoreline. The release of phosphorus from the sediments may be enhanced by the mixing of the water during spring (and fall) turnover.

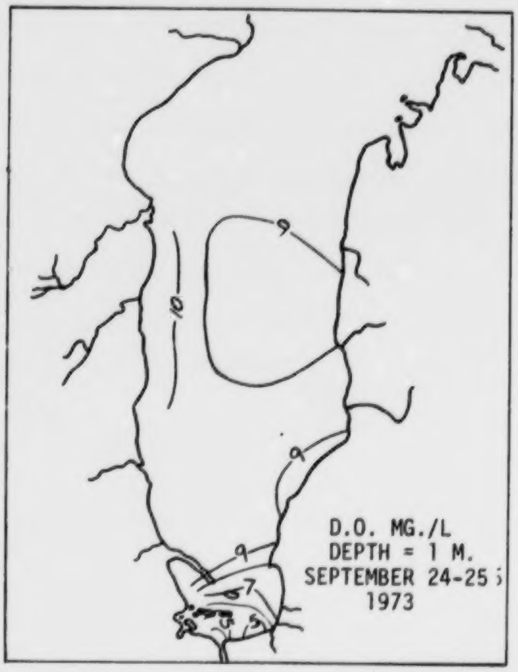
Temperature: In May, temperatures varied from 16°C at the mouth of the Lower Fox River to 7-8°C in the central Bay. Variations in temperature from top to bottom were rarely as much as 1°C. As the summer progressed Bay temperatures not only became warmer but the thermal gradients (top to bottom) increased dramatically. In August, temperatures near the surface ranged from 23°C at the mouth of the Lower Fox River to 18-19°C in the central Bay. At this time, gradients as large as 10°C (top to bottom) were observed in the central Bay.

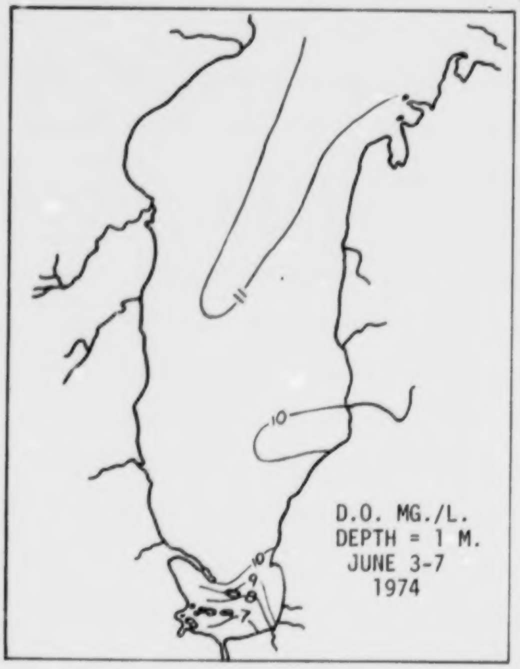
Chlorophyll-a: Chlorophyll-a concentrations generally increased throughout the summer. In May, concentrations of chlorophyll-a in the Inner Bay ranged between 10 and 20 ug/l. Beyond Long Tail Point, Chlorophyll-a concentrations were generally below 10 ug/l. During the summer the chlorophyll-a increased within the Inner Bay at the rate of about 10 ug/l per month. Between July and August this rate of increase jumped dramatically. The concentration went from 30 and 40 ug/l to as high as 100 ug/l. The month of August showed the highest levels of chlorophyll-a at all locations. Concentrations as high as 70 ug/l were found in

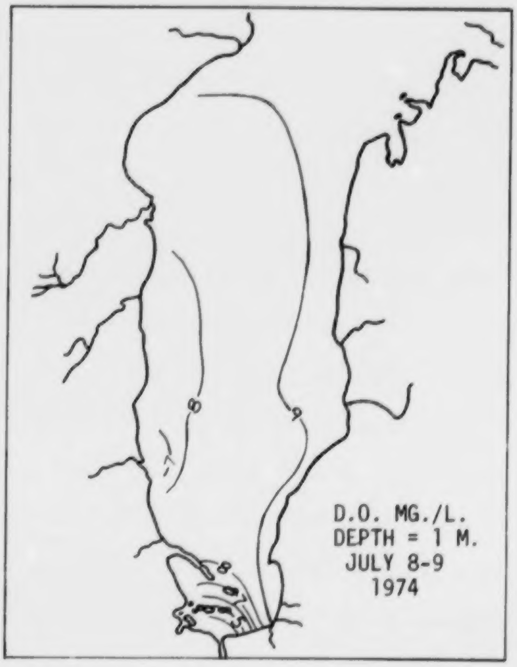
FIGURE III-2

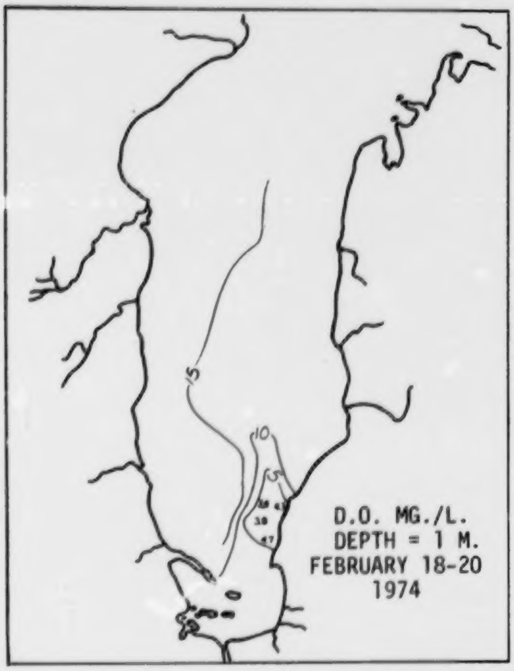
Dissolved Oxygen Contours in Lower Green Bay

The dissolved oxygen was found to be at or above saturation at the one meter depth except very close to the mouth of Lower Fox River. Also during the February survey, very low dissolved oxygen was observed at all depths in the Red Banks area.

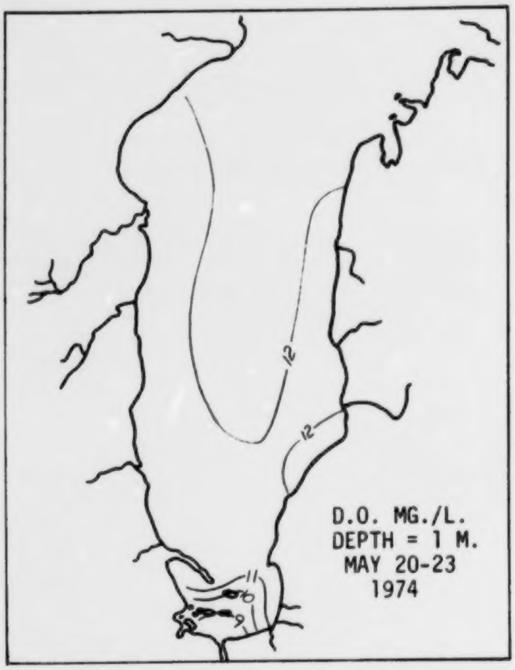

9
10
9
9
7
D.O. MG./L
DEPTH = 1 M.
SEPTEMBER 24-25
1973


11
10
10
9
8
7
D.O. MG./L.
DEPTH = 1 M.
JUNE 3-7
1974

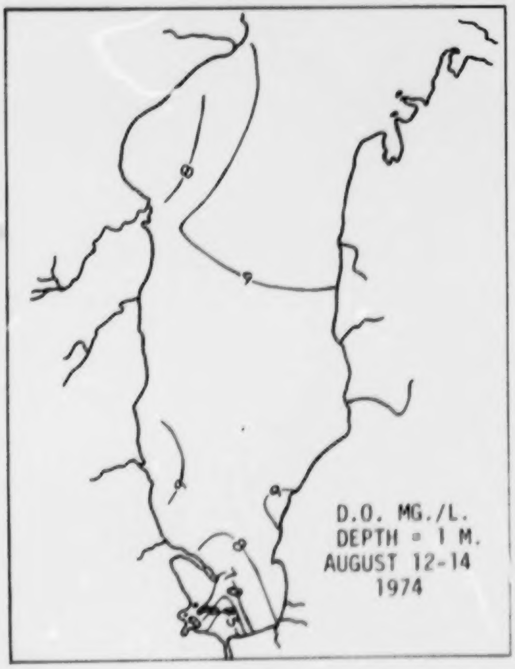

8
9
7
8
D.O. MG./L.
DEPTH = 1 M.
JULY 8-9
1974



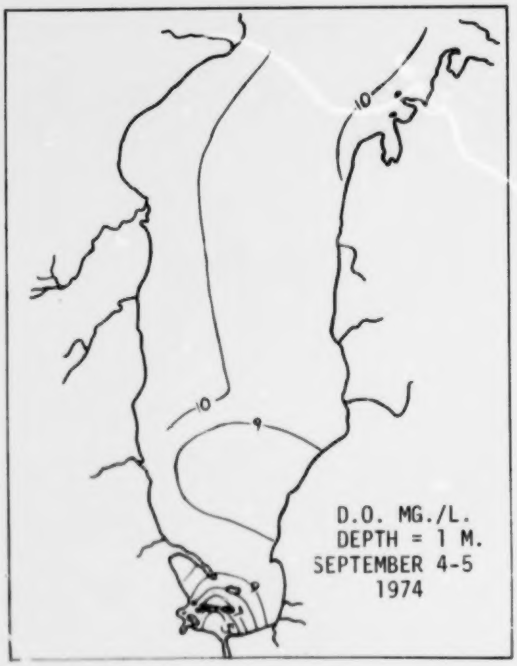
D.O. MG./L.
DEPTH = 1 M.
FEBRUARY 18-20
1974



D.O. MG./L.
DEPTH = 1 M.
MAY 20-23
1974



D.O. MG./L.
DEPTH = 1 M.
AUGUST 12-14
1974

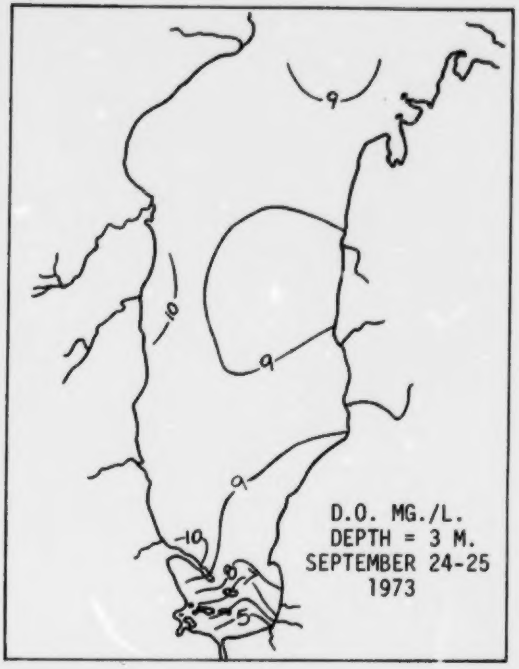


D.O. MG./L.
DEPTH = 1 M.
SEPTEMBER 4-5
1974

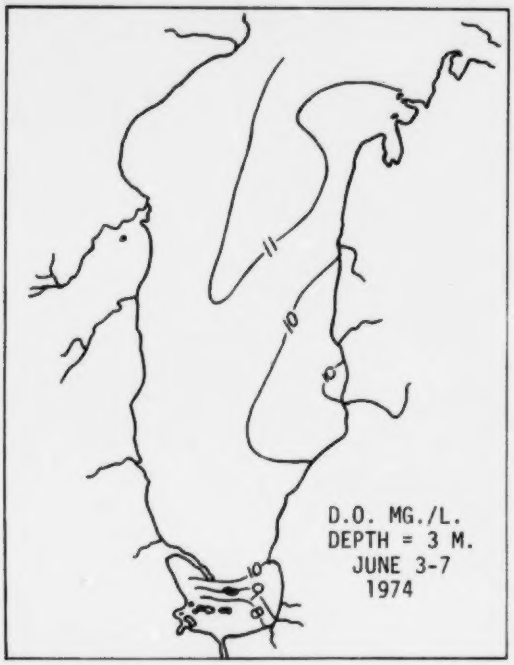
FIGURE III-3

Dissolved Oxygen Contours
in Lower Green Bay

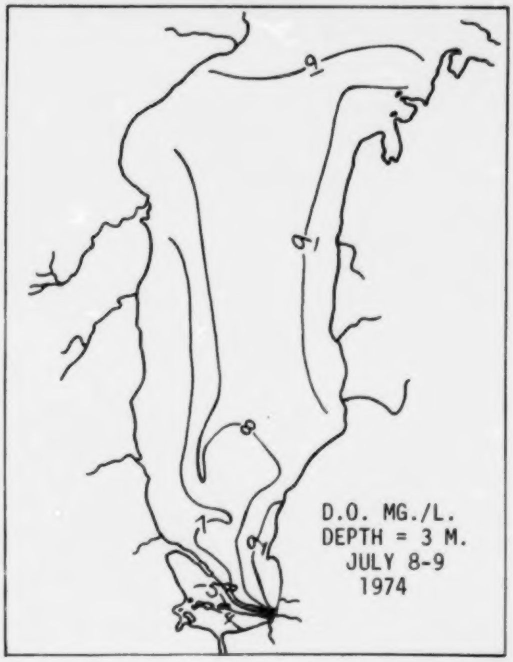
Dissolved oxygen levels at the 3 meter depth were generally high but slightly below the measured values at 1 meter depth. In addition to the areas of low dissolved oxygen mentioned in Figure III-2, depressed DO's were seen at this depth off the mouth of the Oconto River.



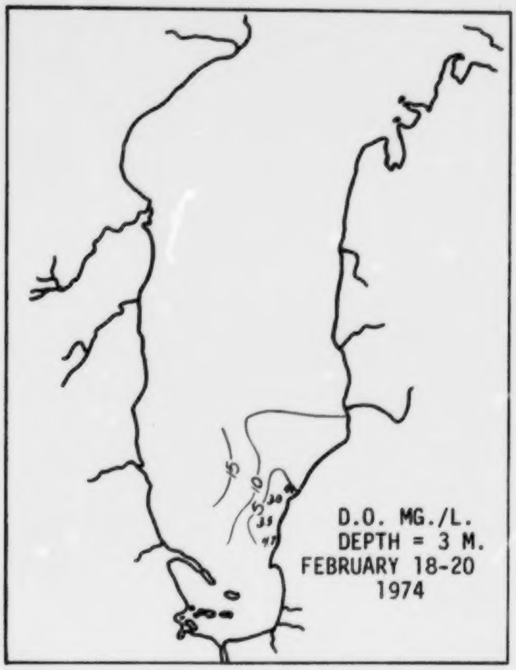
D.O. MG./L.
DEPTH = 3 M.
SEPTEMBER 24-25
1973



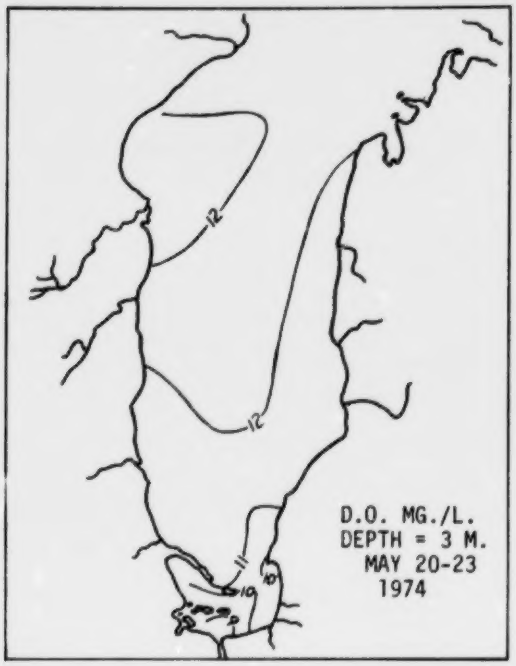
D.O. MG./L.
DEPTH = 3 M.
JUNE 3-7
1974



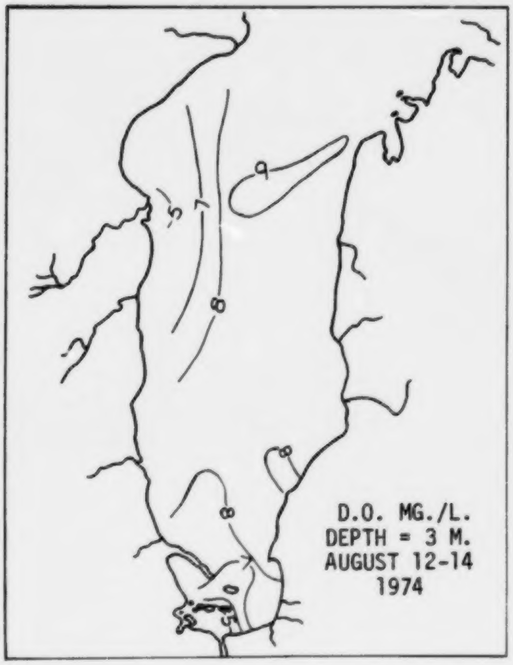
D.O. MG./L.
DEPTH = 3 M.
JULY 8-9
1974


15
10
5
3.0
3.5
4.7

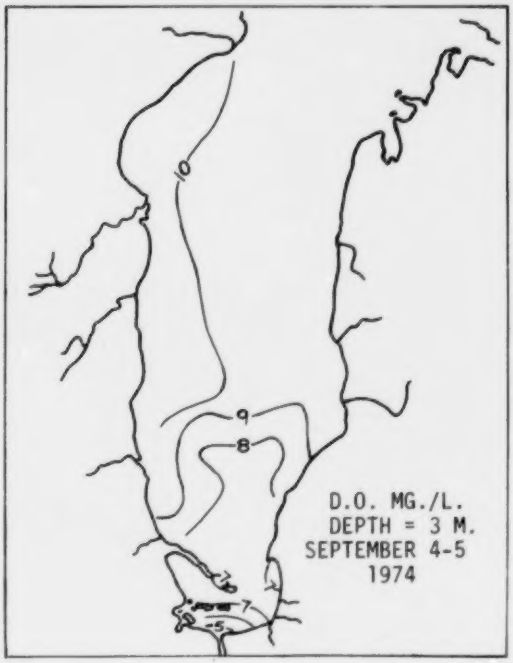
D.O. MG./L.
DEPTH = 3 M.
FEBRUARY 18-20
1974


12
12
11
10
10
9

D.O. MG./L.
DEPTH = 3 M.
MAY 20-23
1974



D.O. MG./L.
DEPTH = 3 M.
AUGUST 12-14
1974

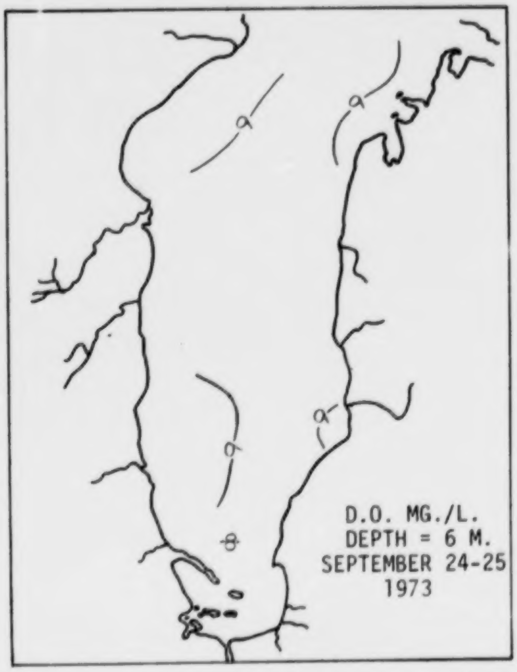


D.O. MG./L.
DEPTH = 3 M.
SEPTEMBER 4-5
1974

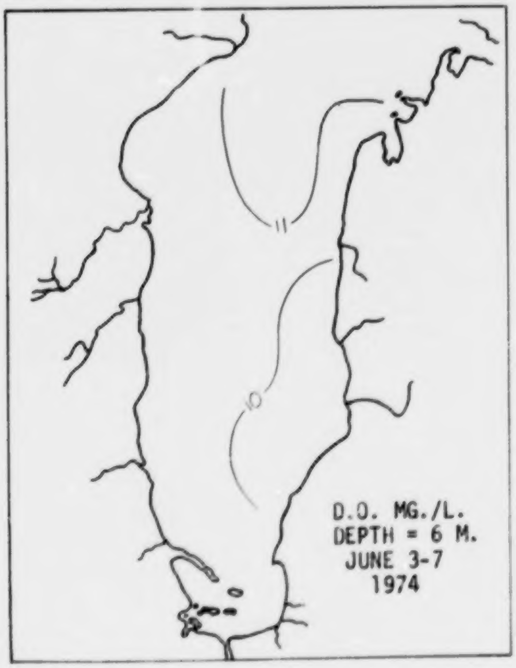
FIGURE III-4

Dissolved Oxygen Contours in Lower Green Bay

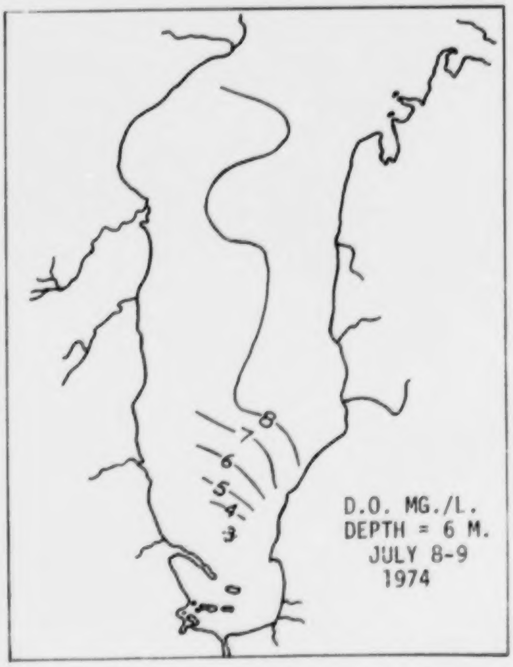
Dissolved oxygen measurements at the 6 meter depth were slightly lower than those at 1 and 3 meters. During July, there was an area beyond Long Tail Point at the 6 meter depth that had low dissolved oxygen levels. This area of low DO may be a result of decaying algae cells or BOD from the Lower Fox River.



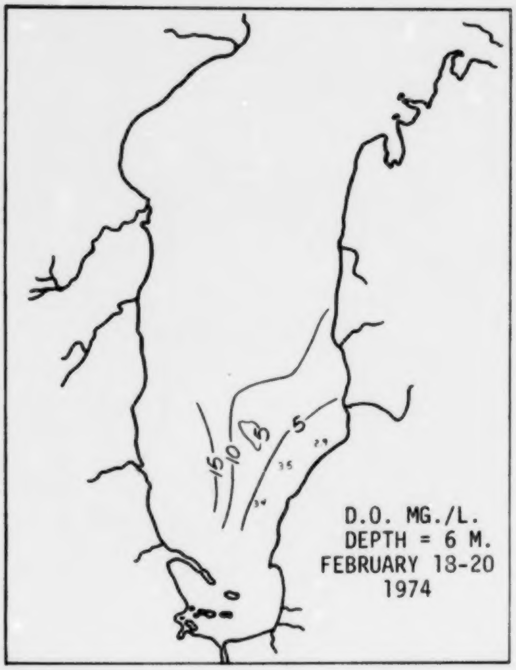
D.O. MG./L.
DEPTH = 6 M.
SEPTEMBER 24-25
1973



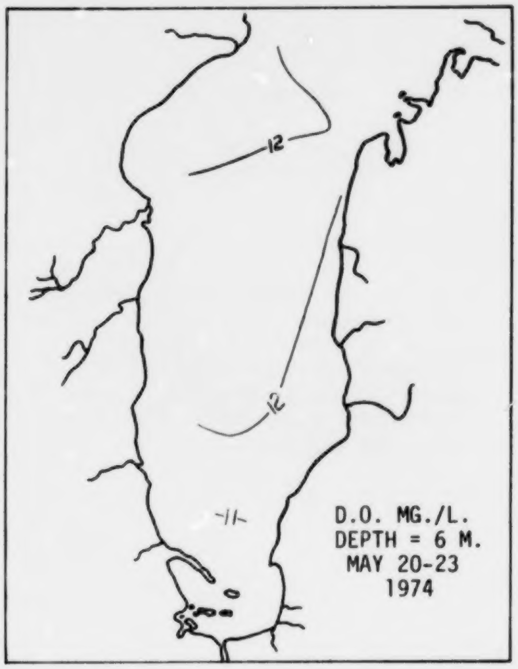
D.O. MG./L.
DEPTH = 6 M.
JUNE 3-7
1974



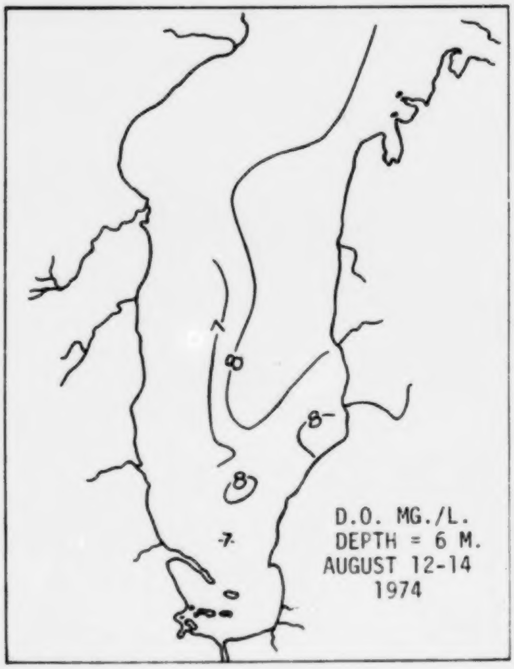
D.O. MG./L.
DEPTH = 6 M.
JULY 8-9
1974


15
10
13
5
29
35
34

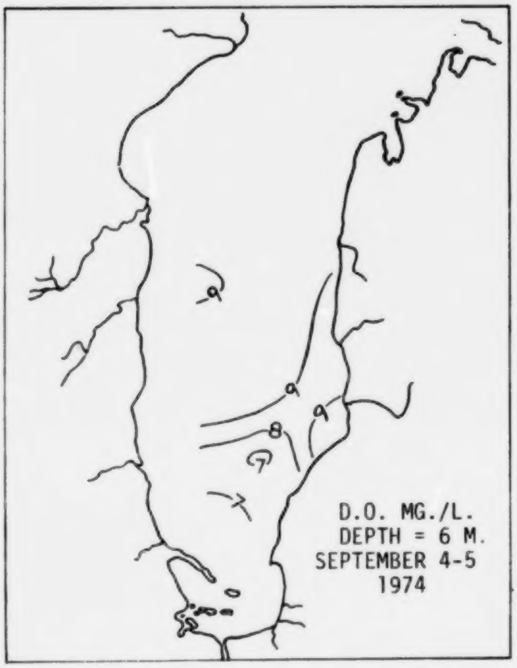
D.O. MG./L.
DEPTH = 6 M.
FEBRUARY 18-20
1974



D.O. MG./L.
DEPTH = 6 M.
MAY 20-23
1974



D.O. MG./L.
DEPTH = 6 M.
AUGUST 12-14
1974

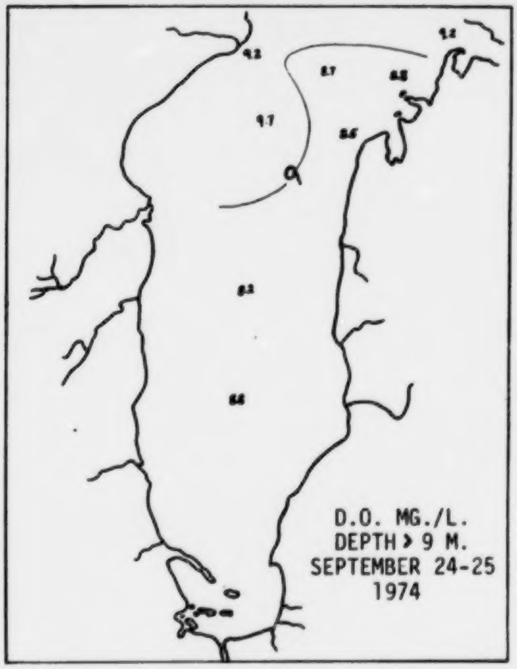


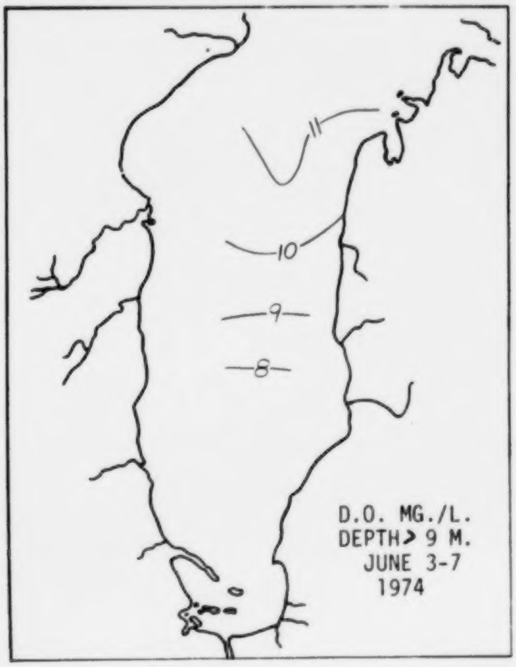
D.O. MG./L.
DEPTH = 6 M.
SEPTEMBER 4-5
1974

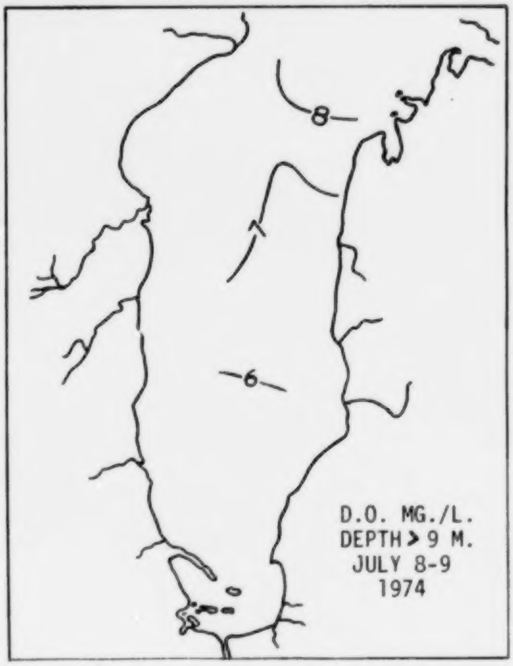
FIGURE III-5

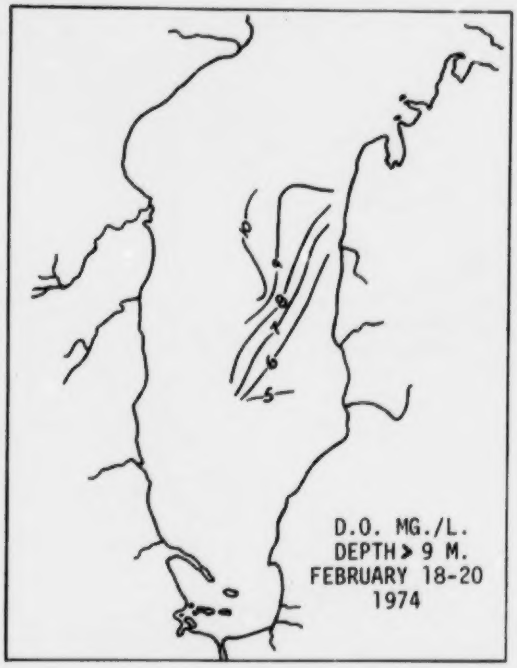
Dissolved Oxygen Contours in Lower Green Bay

Only limited areas of the Lower Bay are deeper than 9 meters. Dissolved oxygen at this depth generally decreased over the course of the summer. This probably is a response to decaying algae cells that sink below the thermocline.

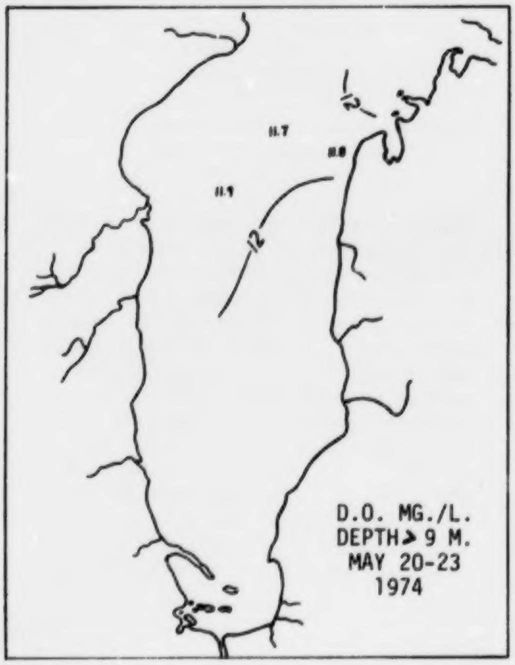

9.2
9.2
8.7
8.8
9.7
8.6
9
8.2
8.6
D.O. MG./L.
DEPTH > 9 M.
SEPTEMBER 24-25
1974


11
10
9
8
D.O. MG./L.
DEPTH > 9 M.
JUNE 3-7
1974

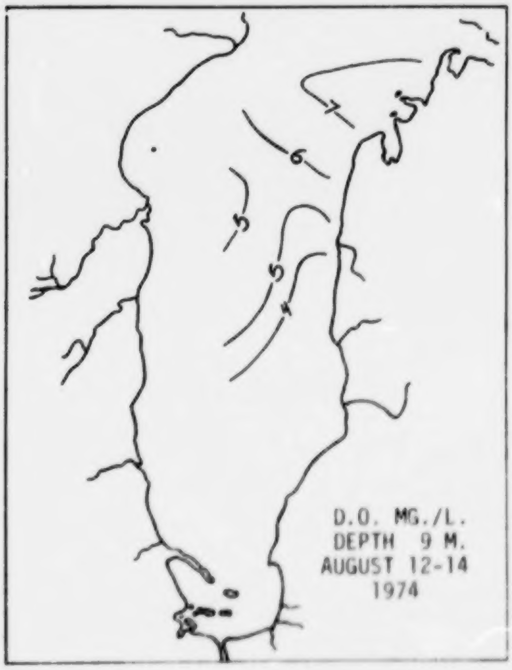

8
7
6
D.O. MG./L.
DEPTH > 9 M.
JULY 8-9
1974



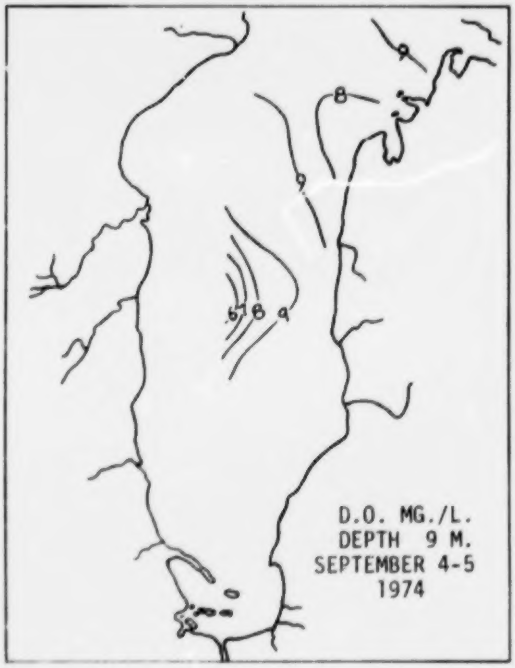
D.O. MG./L.
DEPTH > 9 M.
FEBRUARY 18-20
1974


12
11.7
11.8
11.9
12

D.O. MG./L.
DEPTH > 9 M.
MAY 20-23
1974



D.O. MG./L.
DEPTH 9 M.
AUGUST 12-14
1974

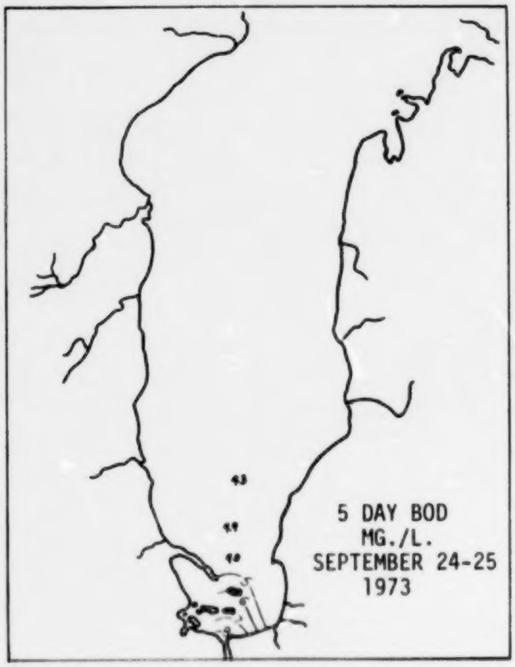


D.O. MG./L.
DEPTH 9 M.
SEPTEMBER 4-5
1974

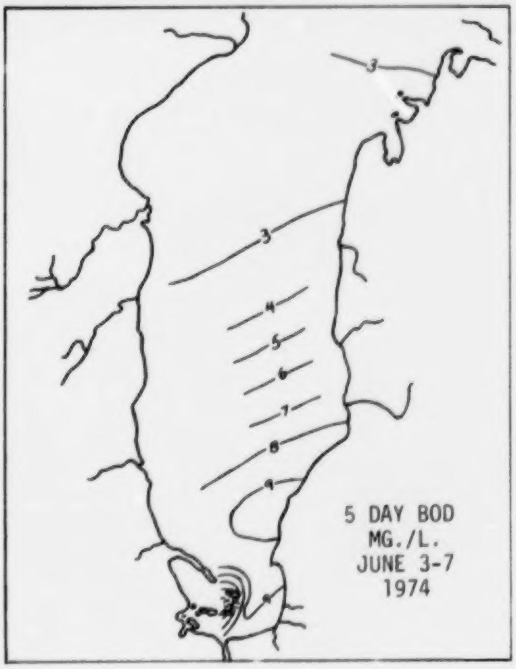
FIGURE III-6

Biochemical Oxygen Demand (BOD_5)
in Lower Green Bay

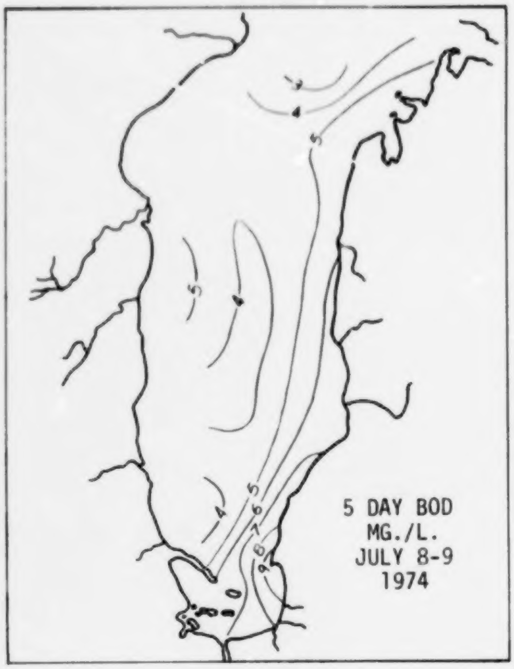
BOD_5 was generally less than 5 mg/l beyond Long Tail Point except in isolated cases. During the winter survey, several samples of high BOD_5 in the area of low dissolved oxygen were found. Samples in the Inner Bay revealed BOD_5 concentrations averaging more than twice those further north. Water samples were taken at the 1 meter depth. In deeper areas (when stratification was apparent from temperature or DO data) a second water sample was taken 2 meters off the bottom. All drawings show only the surface sample.



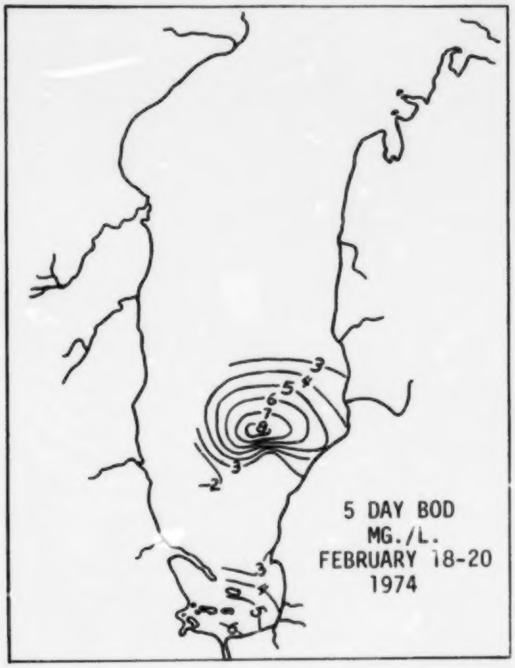
5 DAY BOD
MG./L.
SEPTEMBER 24-25
1973



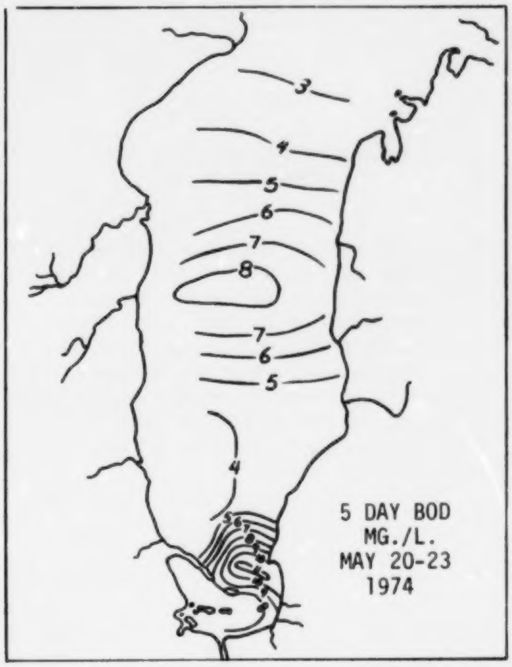
5 DAY BOD
MG./L.
JUNE 3-7
1974



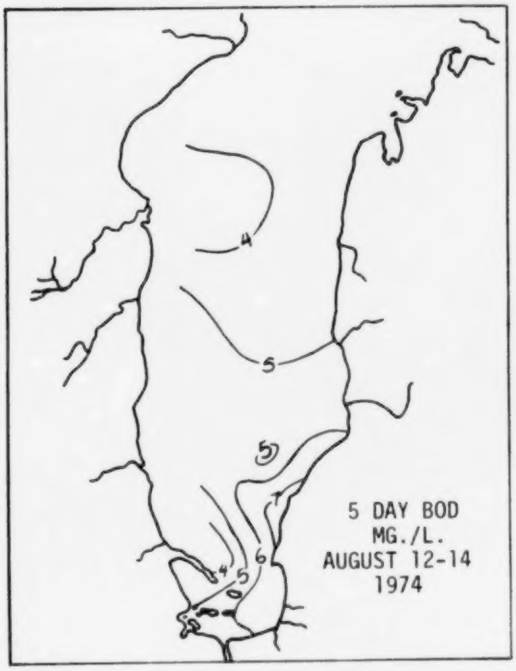
5 DAY BOD
MG./L.
JULY 8-9
1974


3
4
5
6
7
8
3
2
3
4
5

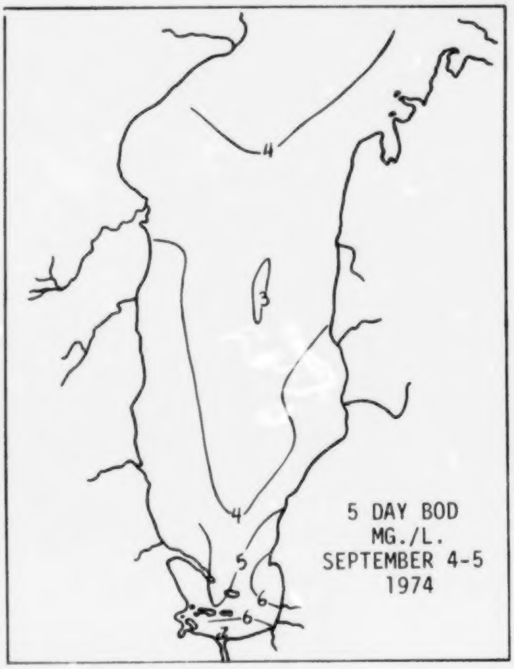
5 DAY BOD
MG./L.
FEBRUARY 18-20
1974


3
4
5
6
7
8
7
6
5
4
5
6
7
8
9

5 DAY BOD
MG./L.
MAY 20-23
1974



5 DAY BOD
MG./L.
AUGUST 12-14
1974

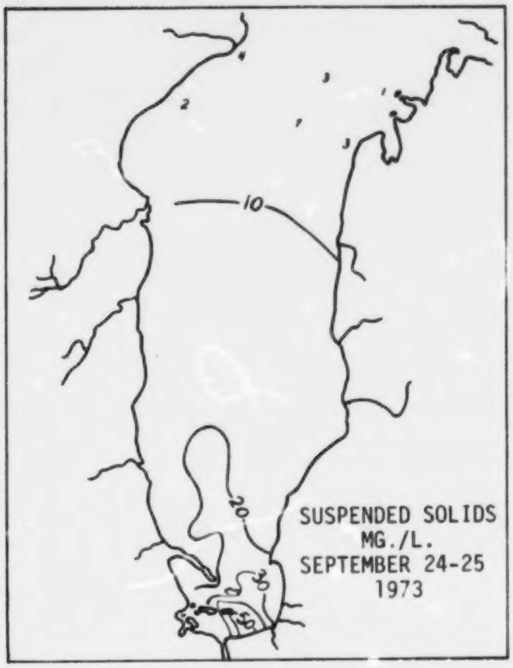


5 DAY BOD
MG./L.
SEPTEMBER 4-5
1974

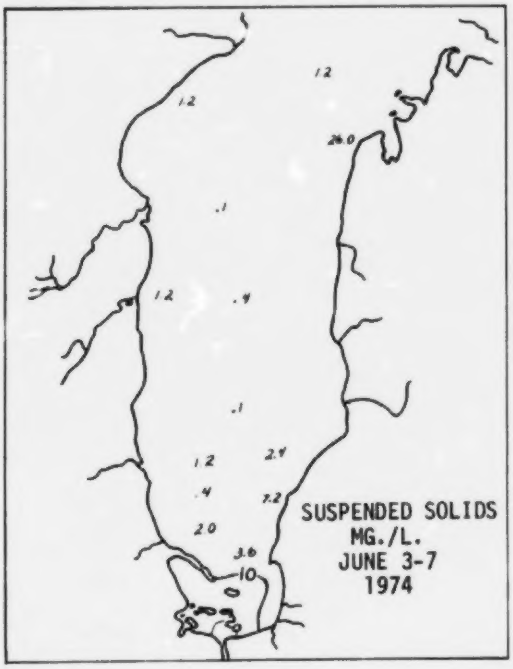
FIGURE III-7

Suspended Solids Contours in Lower Green Bay

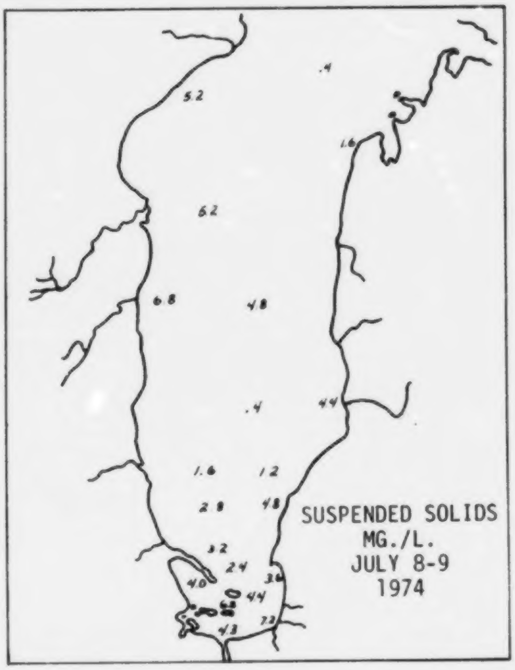
Suspended solids were the highest in all areas of the Bay during the Sept. 1973 survey. Those levels dropped off dramatically by February 1974. May showed a large increase followed by a general decrease until mid-summer. Between August and September of 1974, suspended solids were again increasing especially beyond Long Tail Point.


4
3
2
1
7
3
10
20
30
40

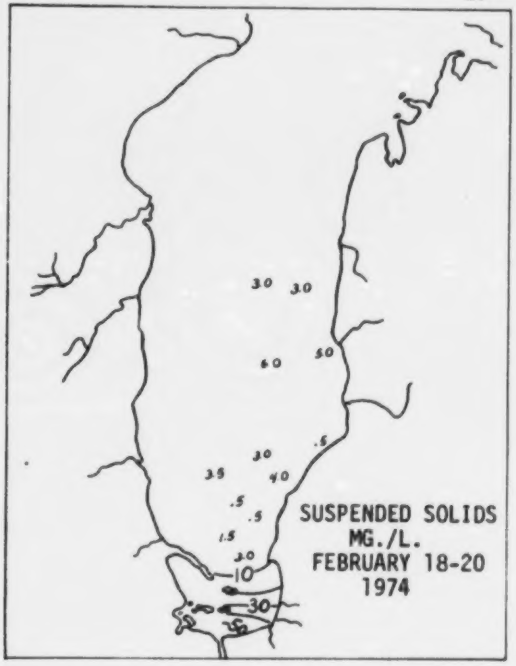
SUSPENDED SOLIDS MG./L. SEPTEMBER 24-25 1973


1.2
1.2
26.0
.1
1.2
.4
.1
1.2
2.4
.4
7.2
2.0
3.6
10

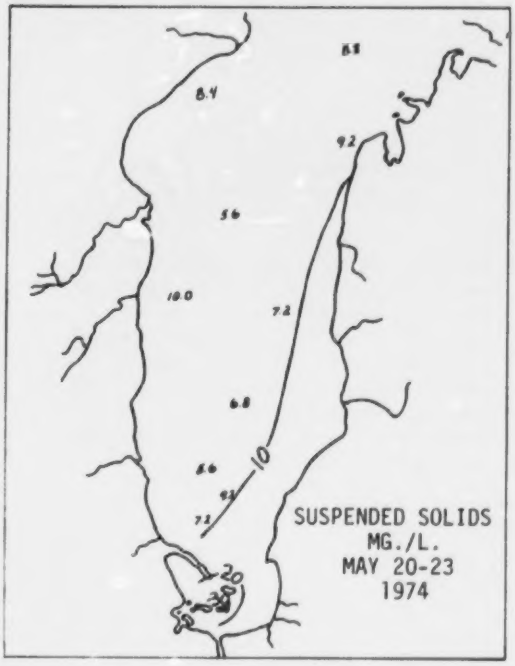
SUSPENDED SOLIDS MG./L. JUNE 3-7 1974


.4
5.2
1.6
6.2
6.8
4.8
.4
4.4
1.6
1.2
2.8
4.8
3.2
2.4
3.6
4.0
4.4
4.3
7.2

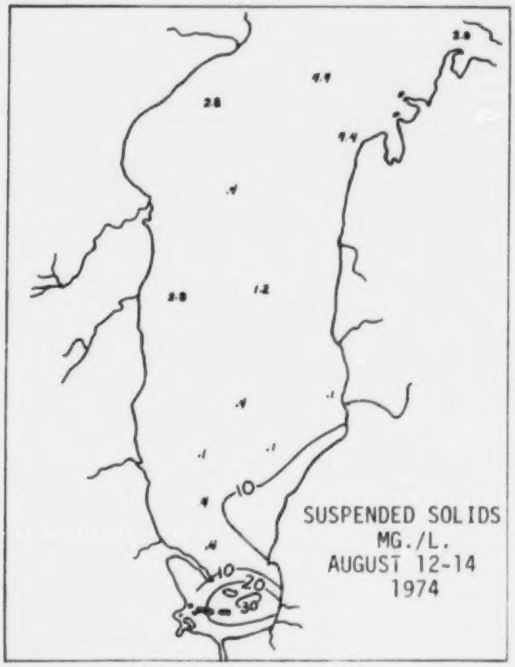
SUSPENDED SOLIDS MG./L. JULY 8-9 1974


3.0
3.0
6.0
5.0
.5
3.0
3.5
4.0
.5
.5
1.5
3.0
10
30
30

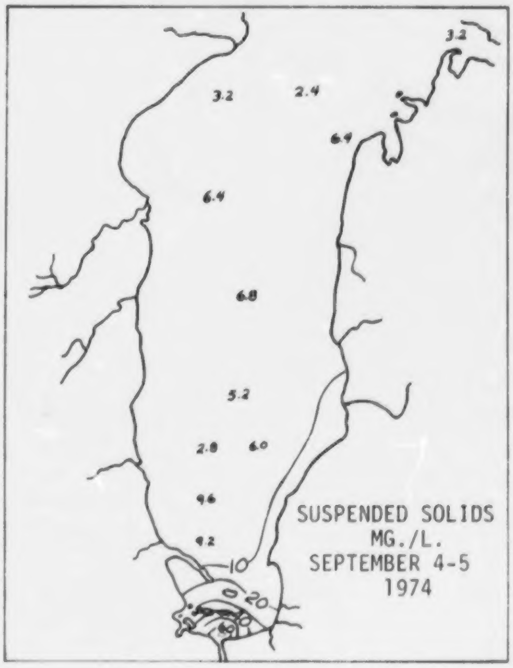
SUSPENDED SOLIDS
MG./L.
FEBRUARY 18-20
1974


8.8
8.4
9.2
5.6
10.0
7.2
6.8
8.6
9.2
7.2
10
20
30

SUSPENDED SOLIDS
MG./L.
MAY 20-23
1974


2.8
4.4
2.8
4.4
.4
2.8
1.2
.4
.1
.1
.1
.4
.4
10
10
20
30

SUSPENDED SOLIDS
MG./L.
AUGUST 12-14
1974

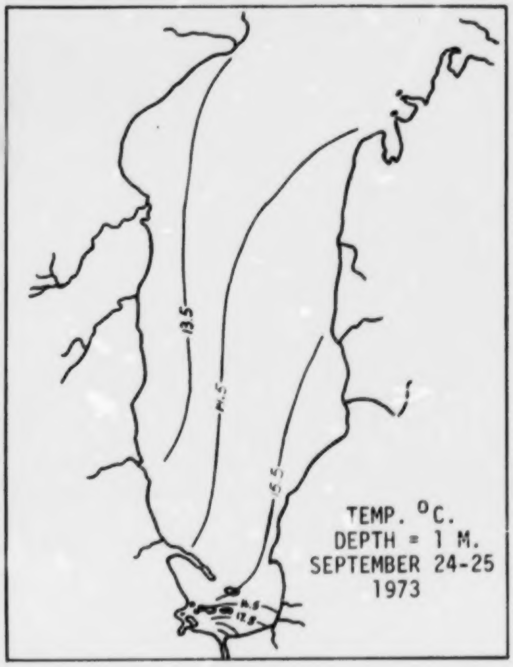

3.2
3.2
2.4
6.4
6.4
6.8
5.2
2.8
6.0
9.6
9.2
10
20
30

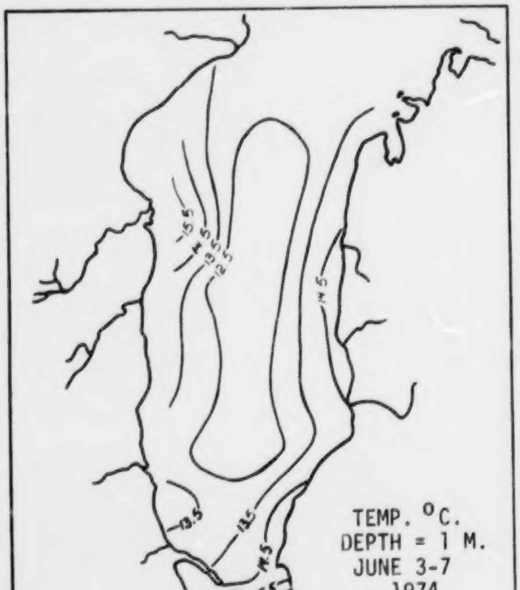
SUSPENDED SOLIDS
MG./L.
SEPTEMBER 4-5
1974

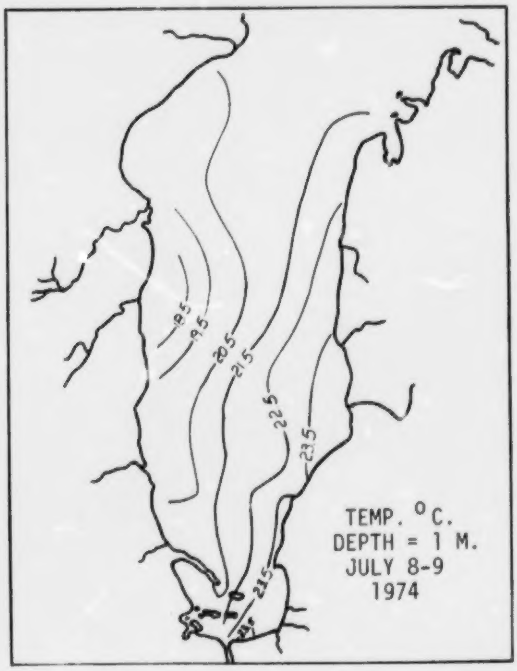
FIGURE III-8

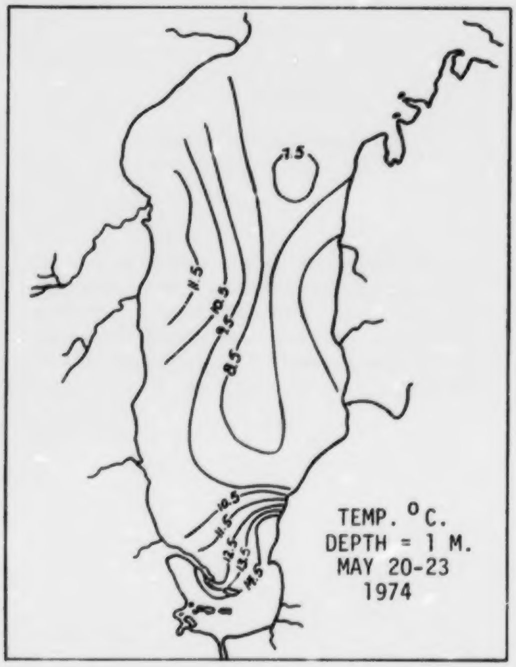
Temperature Contours in Lower Green Bay

Surface temperatures varied about as would be expected through the year. Winter temperatures (not shown) ranged from 0° C to 3° C. Highest temperatures were seen in July when 23.5° C was observed in several areas. In general the water in the Inner Bay averaged 1 to 2° above that in the main area of the Bay.

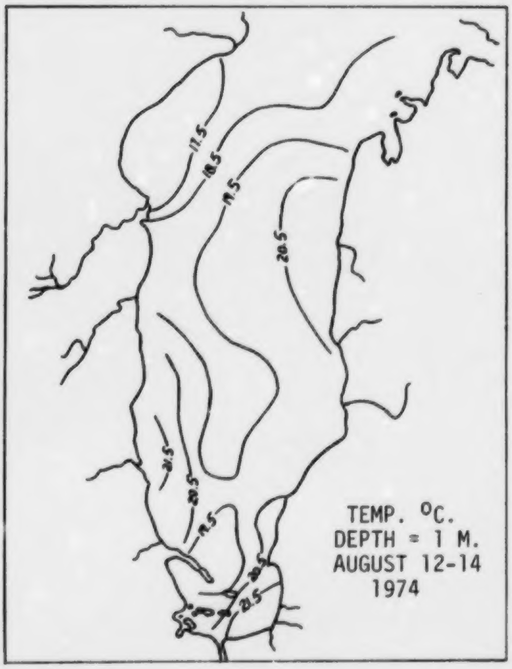

13.5
14.5
15.5
TEMP. °C.
DEPTH = 1 M.
SEPTEMBER 24-25
1973


15.5
14.5
13.5
12.5
14.5
13.5
13.5
14.5
15.5
16.5
14.5
TEMP. °C.
DEPTH = 1 M.
JUNE 3-7
1974

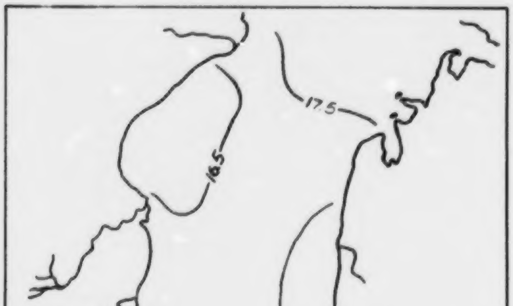

18.5
19.5
20.5
21.5
22.5
23.5
23.5
23.5
TEMP. °C.
DEPTH = 1 M.
JULY 8-9
1974


7.5
11.5
10.5
9.5
8.5
10.5
11.5
12.5
13.5
14.5

TEMP. °C.
DEPTH = 1 M.
MAY 20-23
1974


17.5
18.5
19.5
20.5
21.5
20.5
19.5
20.5
21.5

TEMP. °C.
DEPTH = 1 M.
AUGUST 12-14
1974

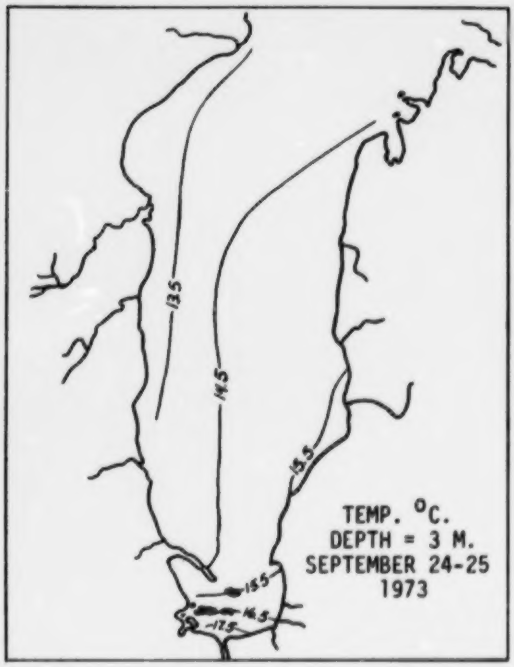

17.5
16.5
17.5
18.5
19.5
18.5
19.5
19.5

TEMP. °C.
DEPTH = 1 M.
SEPTEMBER 4-5
1974

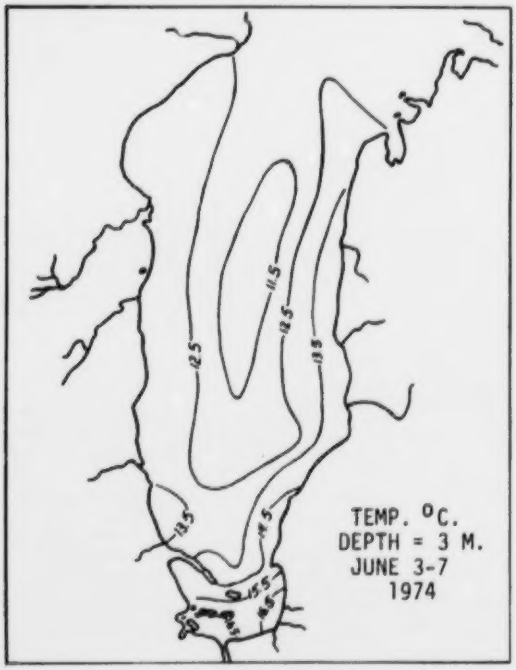
FIGURE III-9

Temperature Contours
in Lower Green Bay

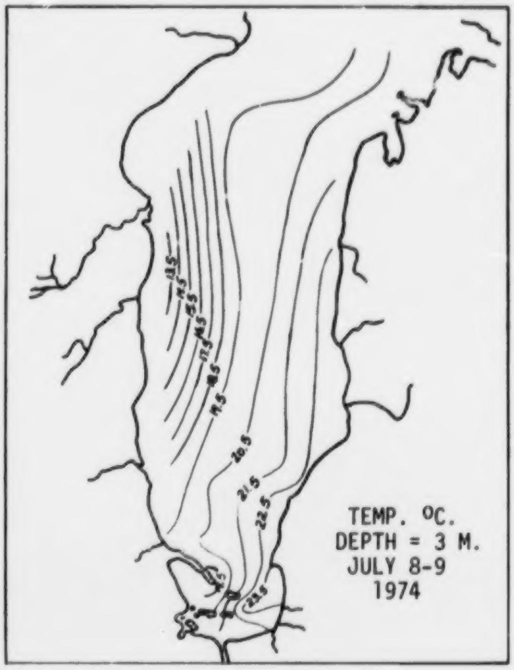
Temperatures at the 3 meter depth did not vary significantly from those at the surface. The difference between the Inner Bay and the outer area was more significant in most surveys ranging up to as much as 5° C.


13.5
14.5
15.5
15.5
16.5
17.5

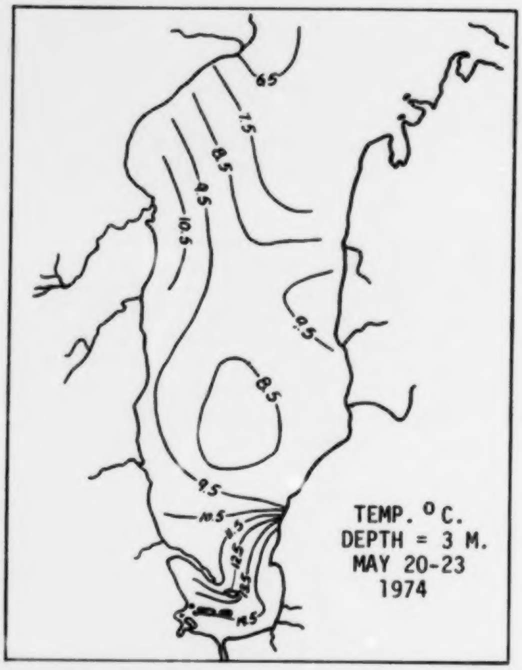
TEMP. °C.
DEPTH = 3 M.
SEPTEMBER 24-25
1973


12.5
11.5
12.5
13.5
13.5
14.5
15.5
16.5

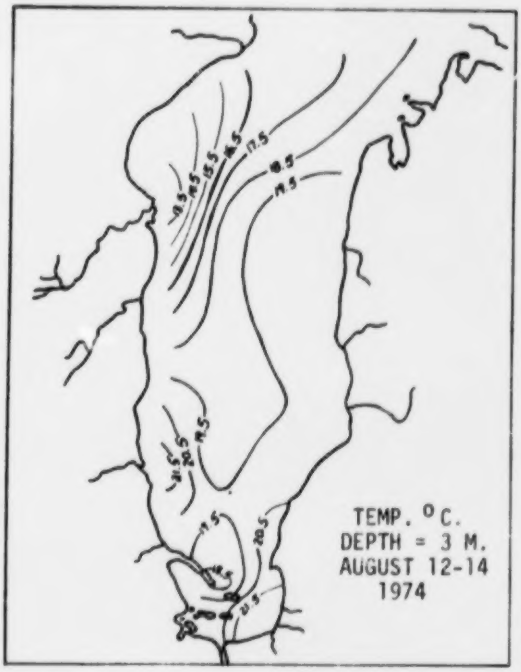
TEMP. °C.
DEPTH = 3 M.
JUNE 3-7
1974


13.5
14.5
15.5
16.5
17.5
18.5
19.5
20.5
21.5
22.5
23.5

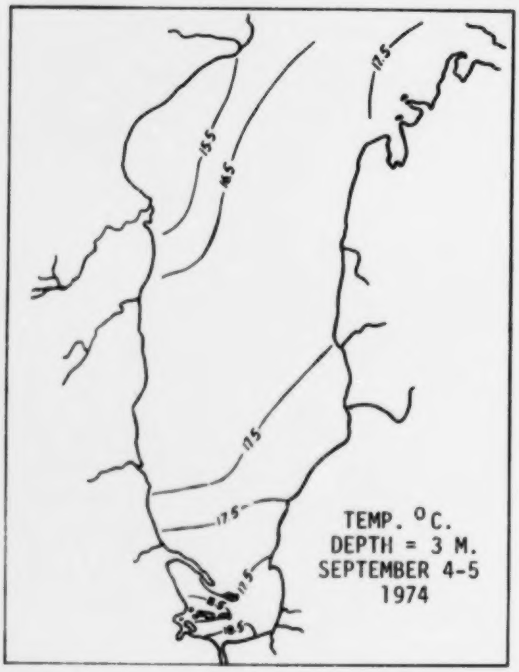
TEMP. °C.
DEPTH = 3 M.
JULY 8-9
1974


6.5
7.5
8.5
9.5
10.5
9.5
8.5
9.5
10.5

TEMP. °C.
DEPTH = 3 M.
MAY 20-23
1974


17.5
18.5
19.5
20.5
19.5
17.5
20.5
21.5

TEMP. °C.
DEPTH = 3 M.
AUGUST 12-14
1974

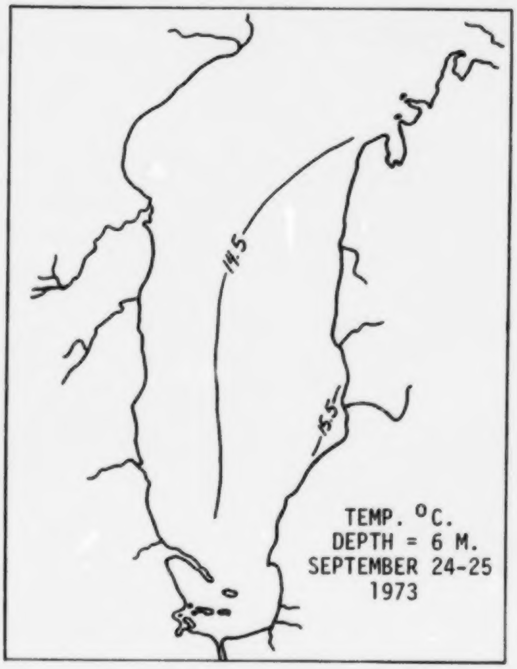

17.5
15.5
16.5
17.5
17.5
17.5
18.5
19.5

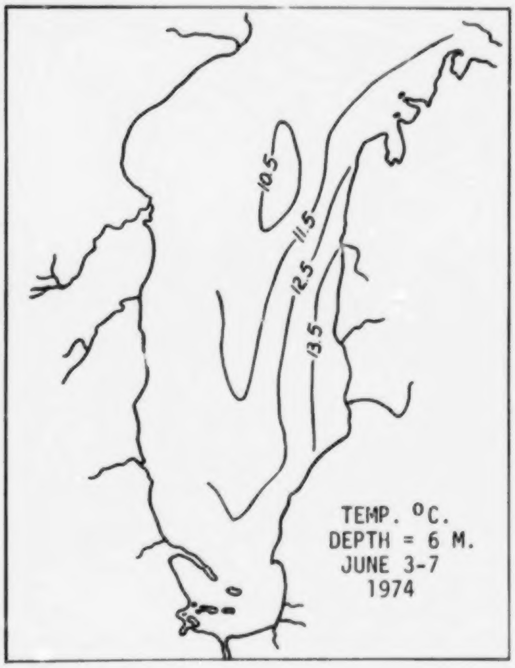
TEMP. °C.
DEPTH = 3 M.
SEPTEMBER 4-5
1974

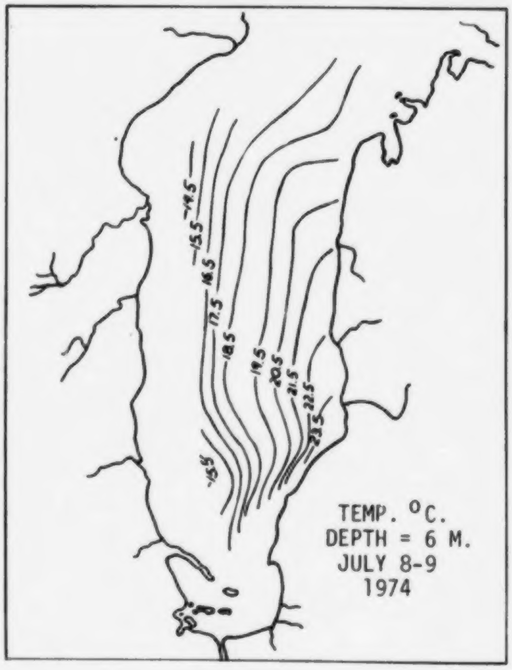
FIGURE III-10

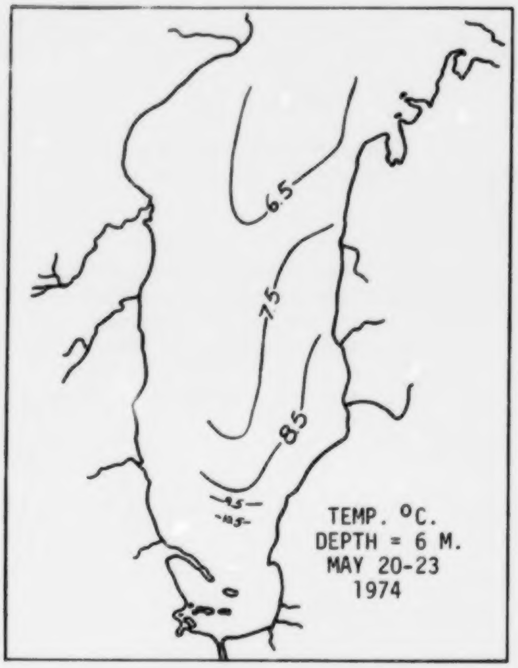
Temperature Contours in Lower Green Bay

The temperature measurements at 6 meters indicated the beginnings of significant pattern changes from those at 3 and 1 meters. Thermal stratification was evidenced in all areas of the Bay where the depth was greater than about 6 meters. The thermocline occurred at about a depth of 6 meters.

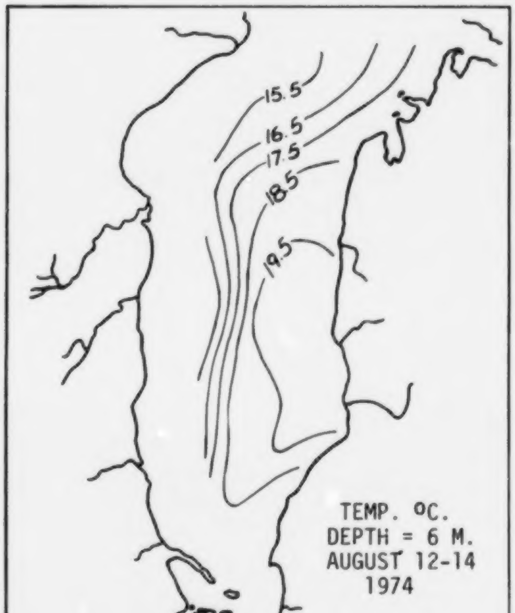

14.5
15.5
TEMP. °C.
DEPTH = 6 M.
SEPTEMBER 24-25
1973


10.5
11.5
12.5
13.5
TEMP. °C.
DEPTH = 6 M.
JUNE 3-7
1974

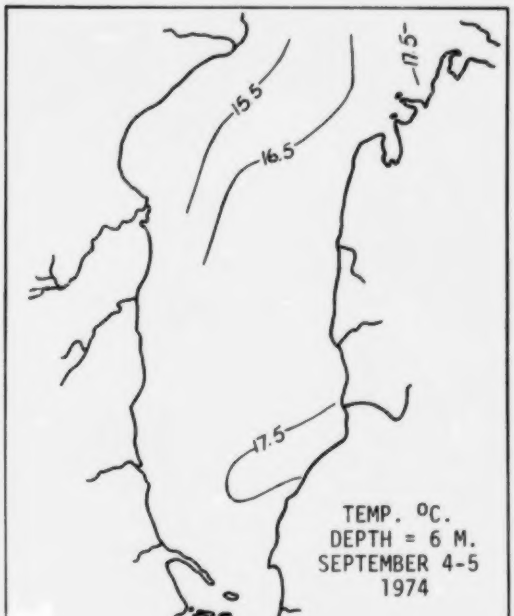

14.5
15.5
16.5
17.5
18.5
19.5
20.5
21.5
22.5
23.5
15.5
TEMP. °C.
DEPTH = 6 M.
JULY 8-9
1974


6.5
7.5
8.5
9.5
10.5

TEMP. °C.
DEPTH = 6 M.
MAY 20-23
1974


15.5
16.5
17.5
18.5
19.5

TEMP. °C.
DEPTH = 6 M.
AUGUST 12-14
1974

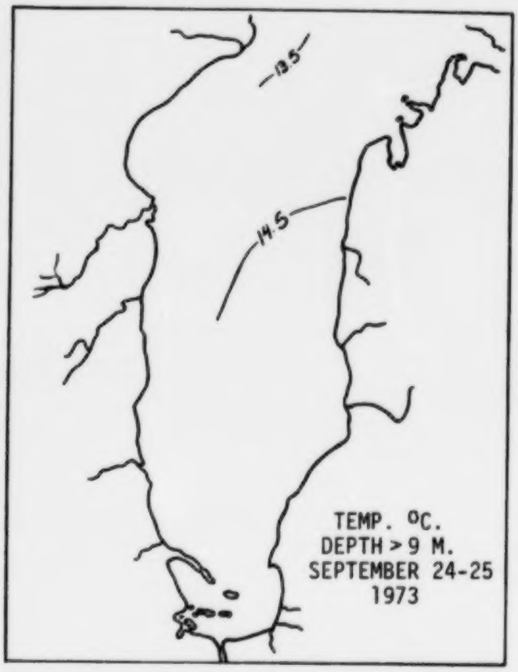

17.5
15.5
16.5
17.5

TEMP. °C.
DEPTH = 6 M.
SEPTEMBER 4-5
1974

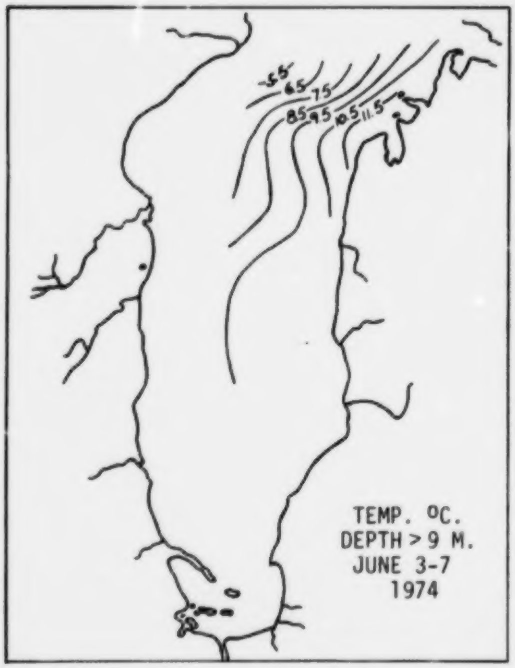
FIGURE III-11

Temperature Contours
in Lower Green Bay

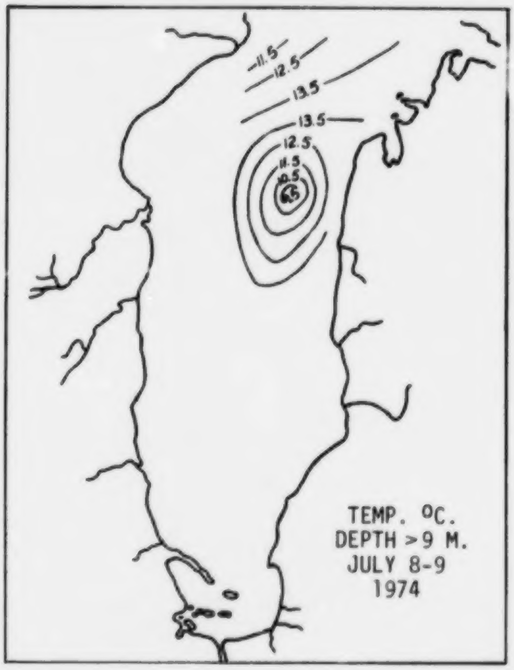
Nearly all the measurements taken at or below 9 meters were below the thermocline. Marked temperature stratification existed in these areas. Vertical gradients as much as 10° C were observed in some areas.



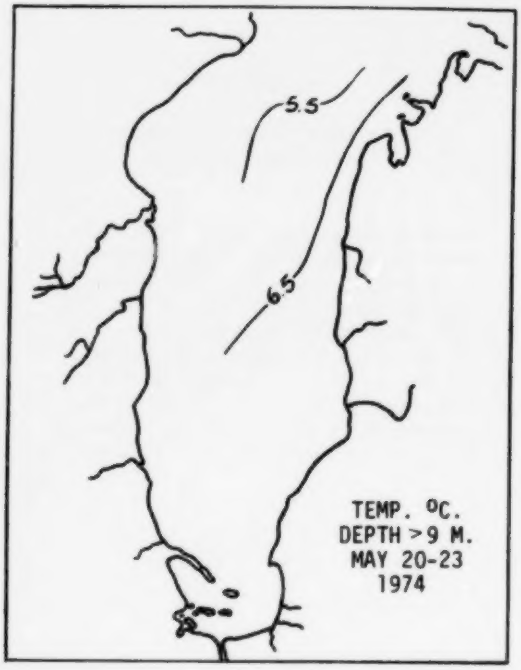
TEMP. °C.
DEPTH > 9 M.
SEPTEMBER 24-25
1973


5.5
6.5
7.5
8.5
9.5
10.5
11.5

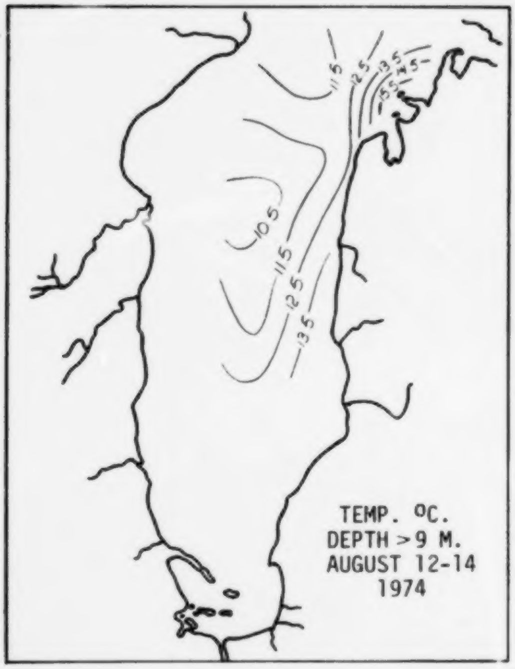
TEMP. °C.
DEPTH > 9 M.
JUNE 3-7
1974


11.5
12.5
13.5
13.5
12.5
11.5
10.5

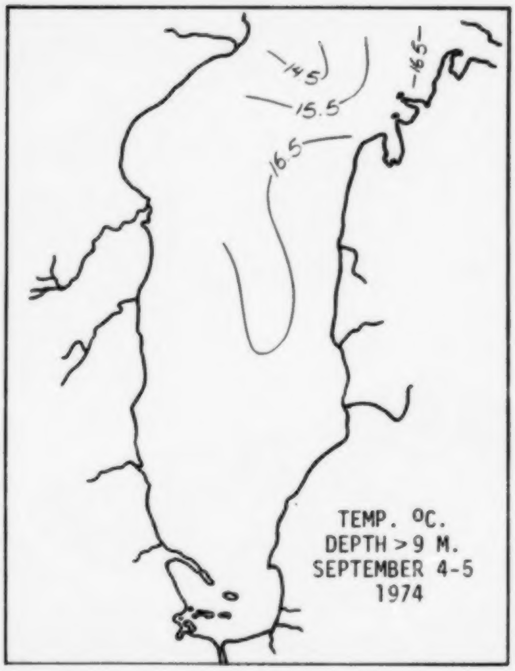
TEMP. °C.
DEPTH > 9 M.
JULY 8-9
1974



TEMP. °C.
DEPTH > 9 M.
MAY 20-23
1974


11.5
12.5
13.5
14.5
15.5
10.5
11.5
12.5
13.5

TEMP. °C.
DEPTH > 9 M.
AUGUST 12-14
1974

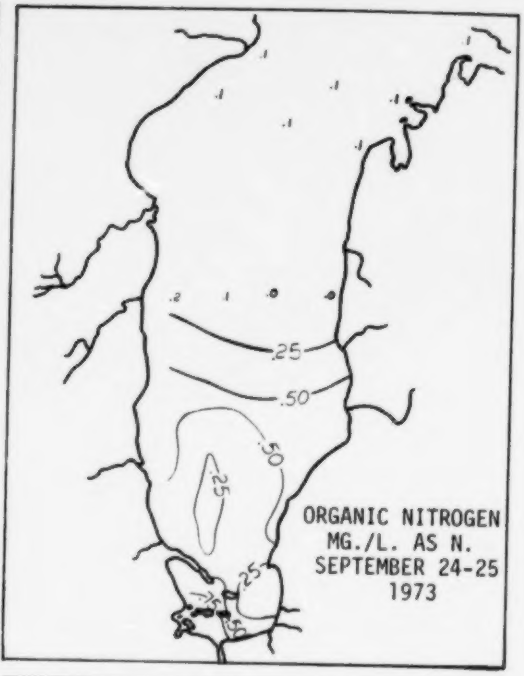

14.5
15.5
16.5
16.5

TEMP. °C.
DEPTH > 9 M.
SEPTEMBER 4-5
1974

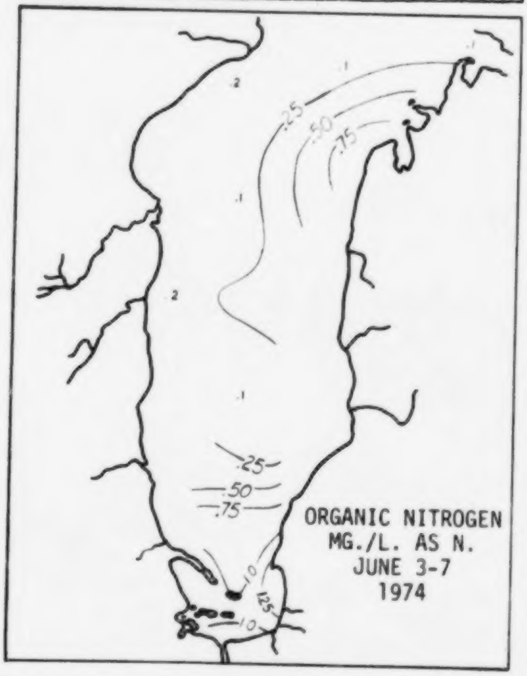
FIGURE III-12

Organic Nitrogen Contours
in Lower Green Bay

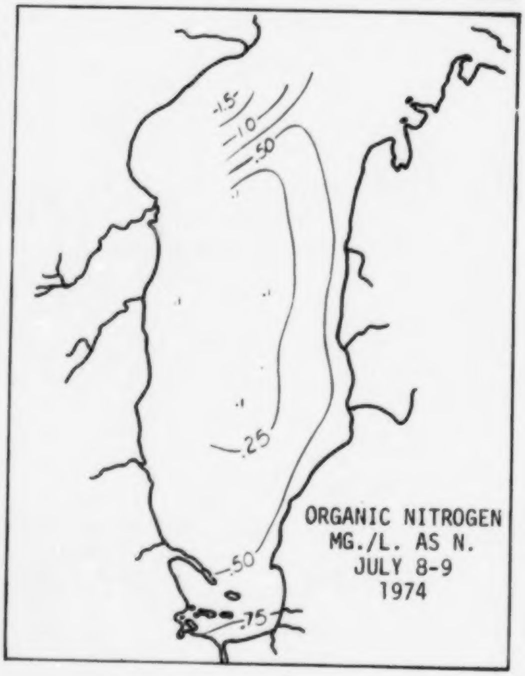
Organic nitrogen levels fluctuated considerably in the Bay, probably in response to various algae blooms. During the February survey of 1974, high levels of organic nitrogen were observed in the Dykesville area indicating a possible winter algal bloom. Organic nitrogen in the Inner Bay generally exceeded .75 mg/l except for the February and May surveys.


.1
.1
.1
.1
.1
.1
.2
.1
.25
.50
.50
.25
.25
.50

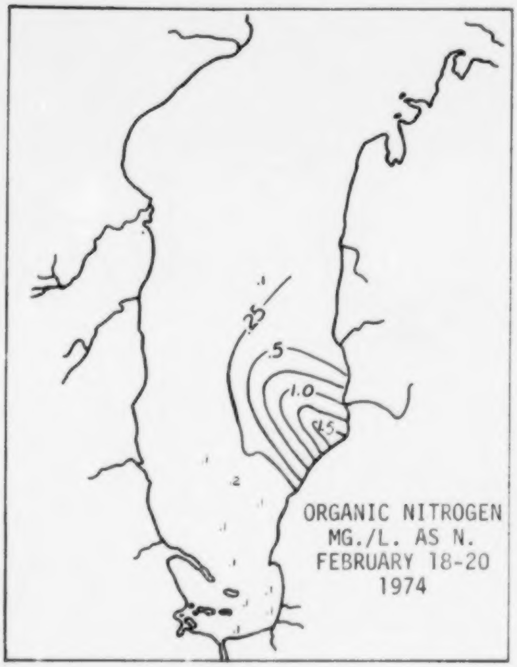
ORGANIC NITROGEN
MG./L. AS N.
SEPTEMBER 24-25
1973


.2
.1
.25
.50
.75
.1
.2
.1
.25
.50
.75
1.0
1.25
1.0

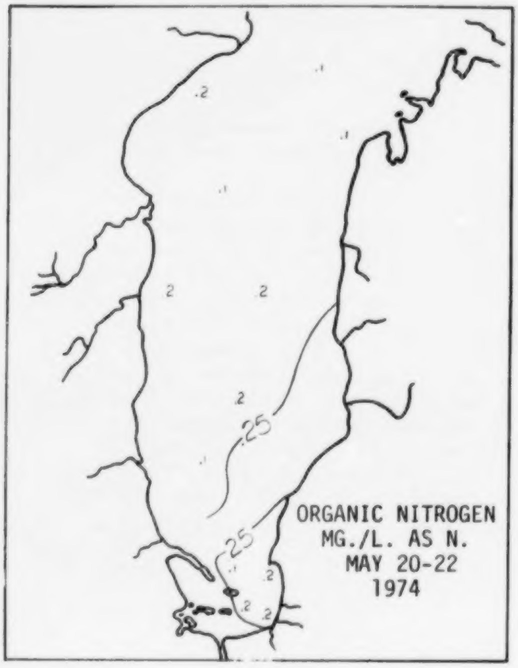
ORGANIC NITROGEN
MG./L. AS N.
JUNE 3-7
1974


1.5
1.0
.50
.1
.1
.1
.25
.50
.75

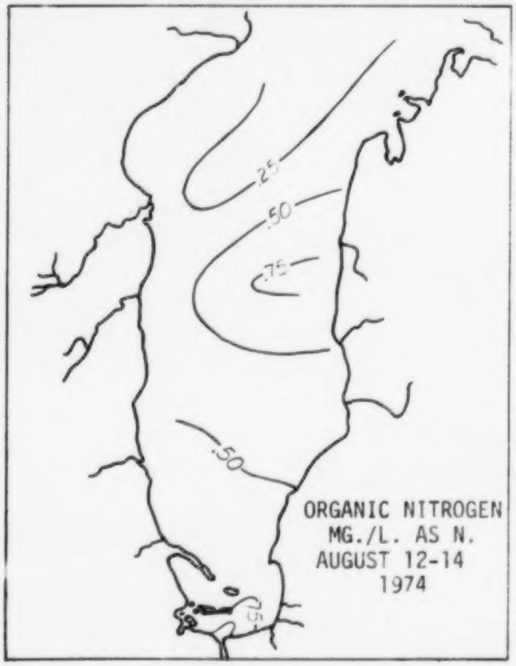
ORGANIC NITROGEN
MG./L. AS N.
JULY 8-9
1974


.1
.25
.5
1.0
1.5
.2
.1

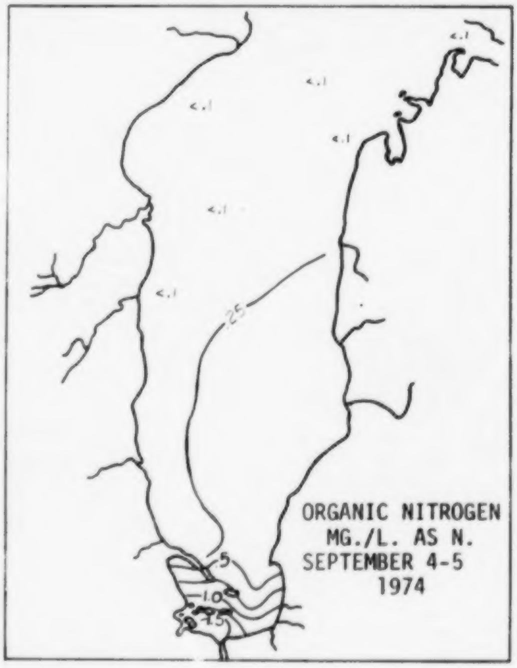
ORGANIC NITROGEN
MG./L. AS N.
FEBRUARY 18-20
1974


.2
.1
.2
.2
.2
.25
.25
.2

ORGANIC NITROGEN
MG./L. AS N.
MAY 20-22
1974


.25
.50
.75
.50
.75

ORGANIC NITROGEN
MG./L. AS N.
AUGUST 12-14
1974

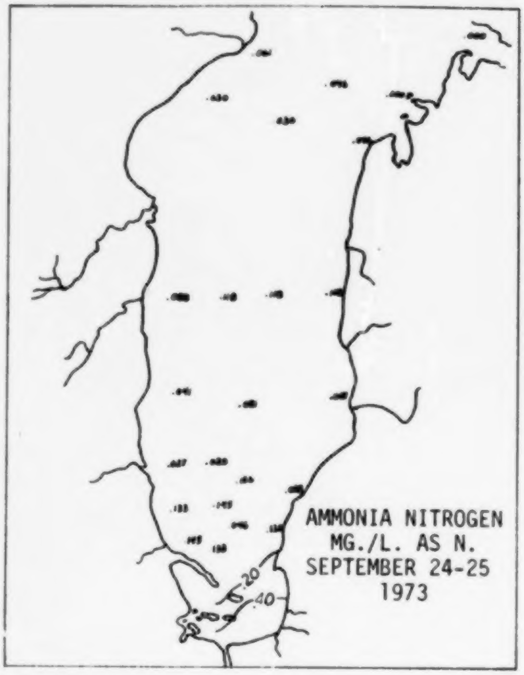


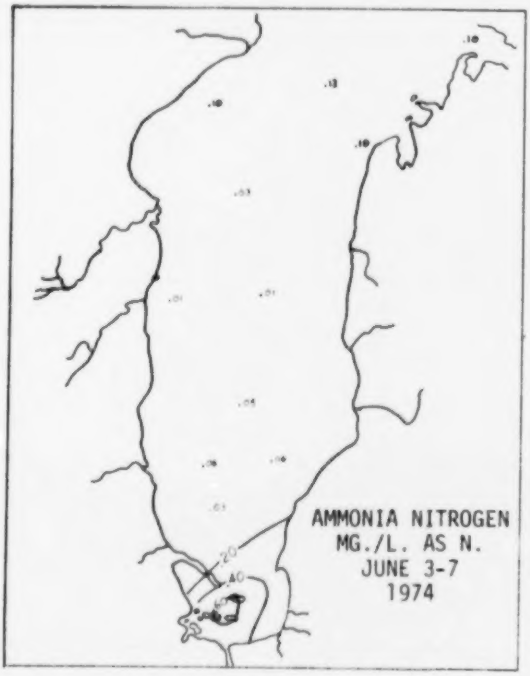
ORGANIC NITROGEN
MG./L. AS N.
SEPTEMBER 4-5
1974

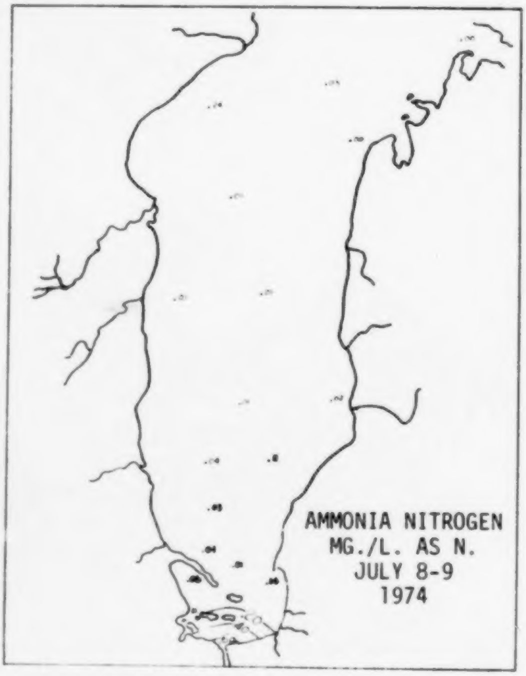
FIGURE III-13

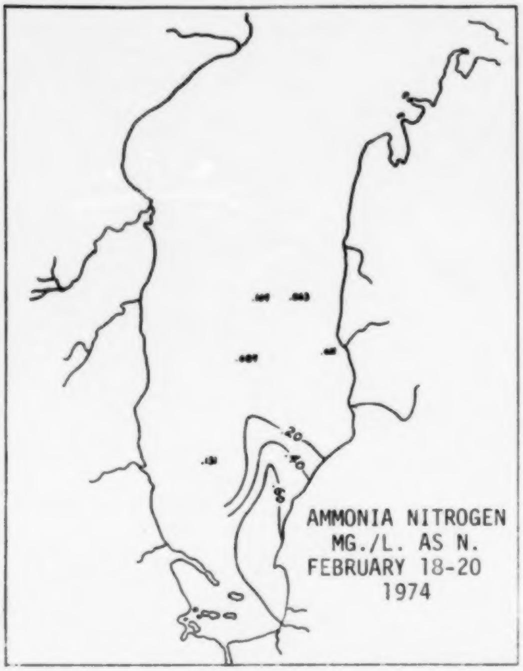
Ammonia Nitrogen Contours
in Lower Green Bay

Ammonia concentrations showed a regular pattern of decrease in the Inner Bay on all summer surveys. Concentrations between .8 and .2 mg/l were regularly found in the Inner Bay. Only during winter, when nitrification is slowed by cold temperatures, did higher ammonia levels reach as far north as Dykesville. Concentrations in the area north of Long Tail Point generally fell to a very low level during the summer.

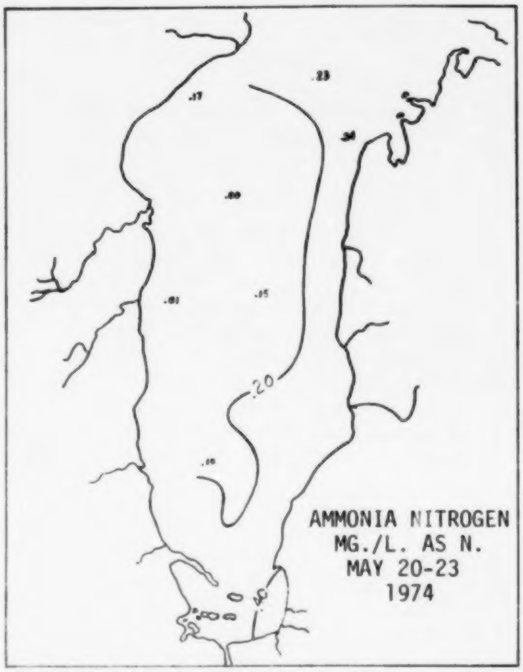

AMMONIA NITROGEN
MG./L. AS N.
SEPTEMBER 24-25
1973
.20
.40


AMMONIA NITROGEN
MG./L. AS N.
JUNE 3-7
1974
.20
.40

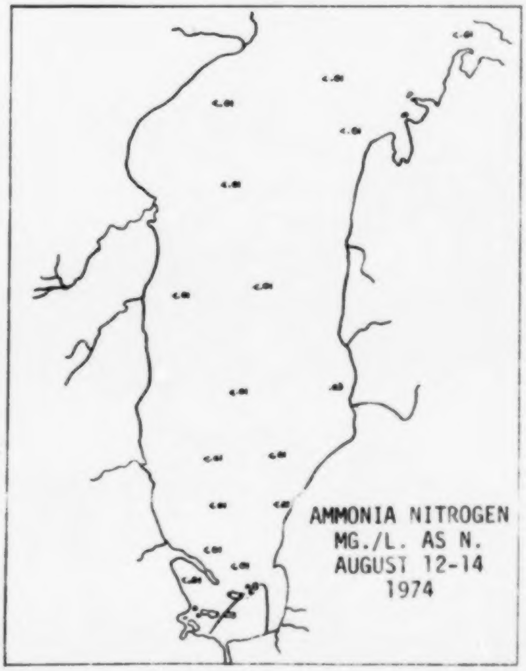

AMMONIA NITROGEN
MG./L. AS N.
JULY 8-9
1974
.40



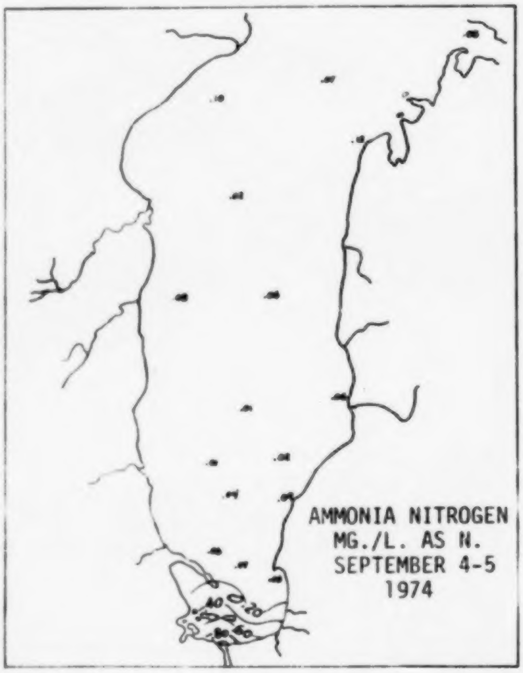
AMMONIA NITROGEN
MG./L. AS N.
FEBRUARY 18-20
1974



AMMONIA NITROGEN
MG./L. AS N.
MAY 20-23
1974



AMMONIA NITROGEN
MG./L. AS N.
AUGUST 12-14
1974

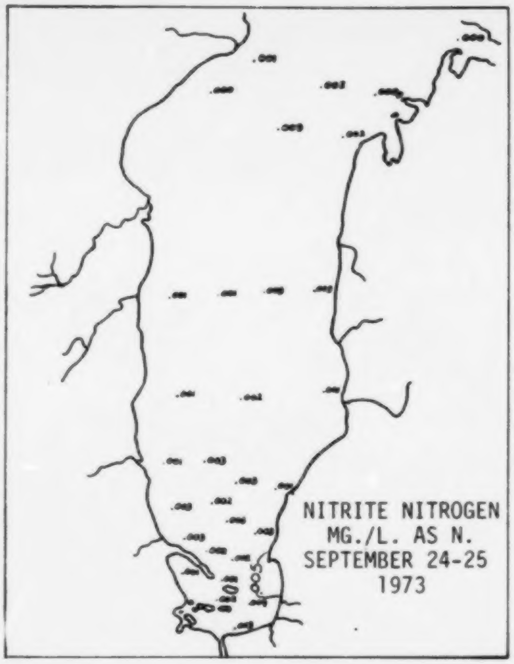


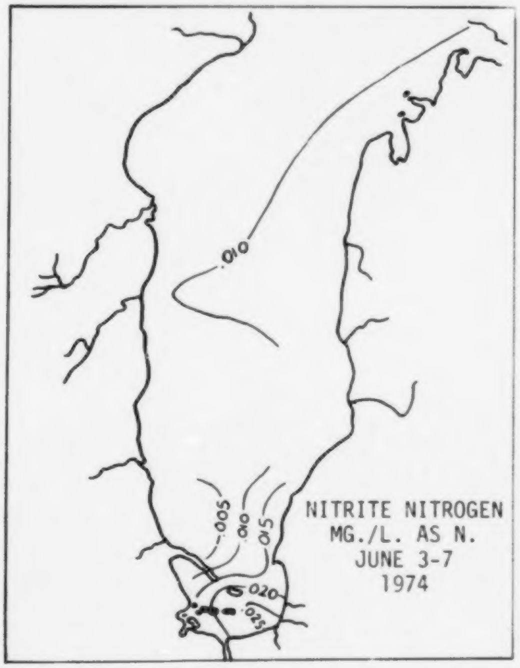
AMMONIA NITROGEN
MG./L. AS N.
SEPTEMBER 4-5
1974

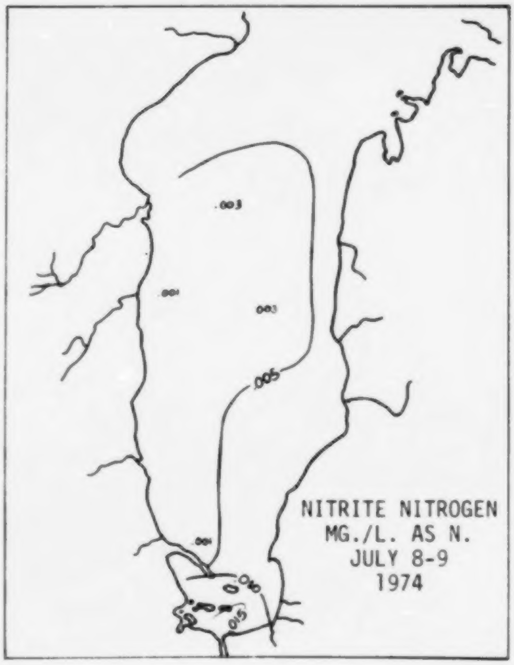
FIGURE III-14

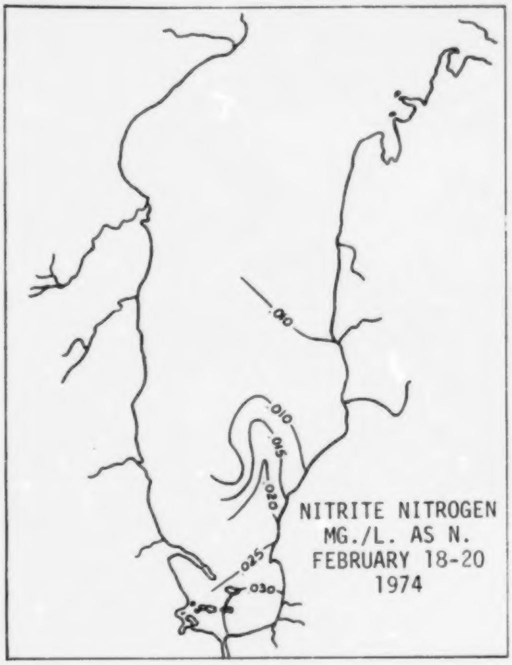
Nitrite Nitrogen Contours in Lower Green Bay

Nitrite concentrations were highest in the Inner Bay. The winter survey revealed the highest concentration of nitrite observed in this study reaching levels of .030 mg/l. The concentration in the northern part of the Bay fluctuated by about one order of magnitude. The lowest observed values were seen on the September 1973 and July 1974 surveys.

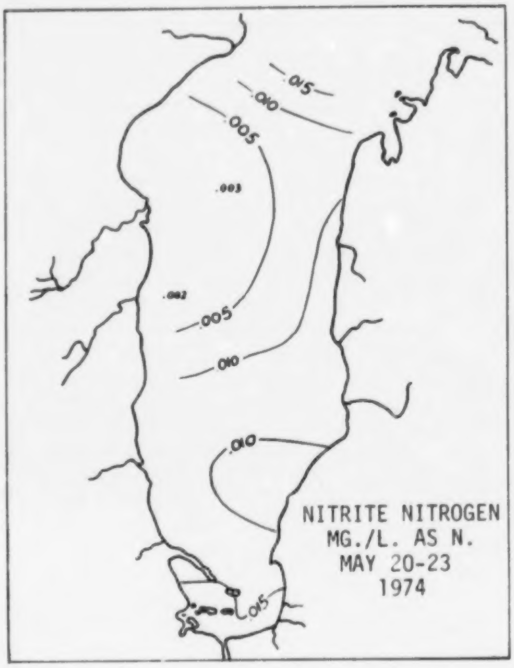

.005
NITRITE NITROGEN
MG./L. AS N.
SEPTEMBER 24-25
1973


.010
.005
.010
.015
.020
.025
NITRITE NITROGEN
MG./L. AS N.
JUNE 3-7
1974

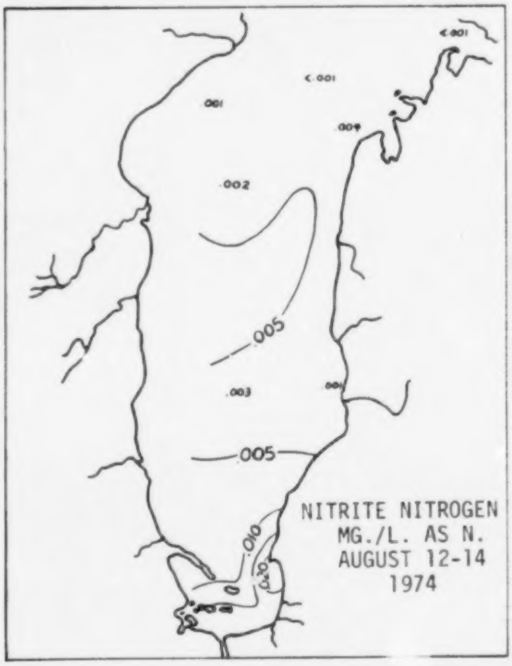

.003
.001
.003
.005
.001
.010
.015
NITRITE NITROGEN
MG./L. AS N.
JULY 8-9
1974


.010
.010
.015
.020
.025
.030

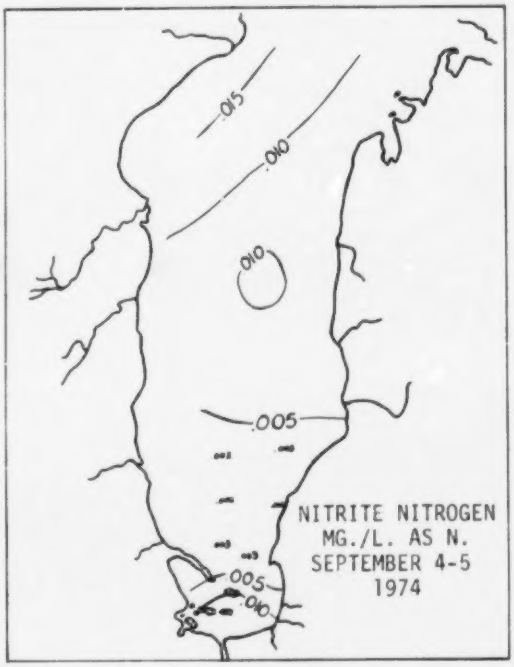
NITRITE NITROGEN
MG./L. AS N.
FEBRUARY 18-20
1974


.015
.010
.005
.003
.002
.005
.010
.010
.015

NITRITE NITROGEN
MG./L. AS N.
MAY 20-23
1974


<.001
<.001
.001
.004
.002
.005
.003
.001
.005
.010
.020

NITRITE NITROGEN
MG./L. AS N.
AUGUST 12-14
1974

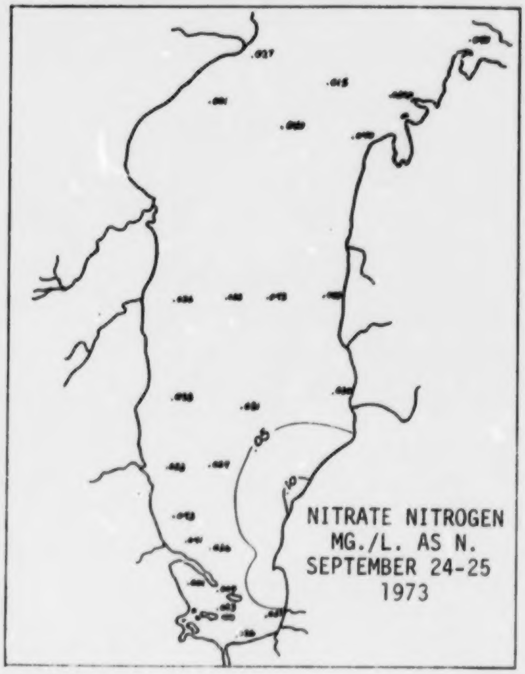

.015
.010
.010
.005
.005
.010

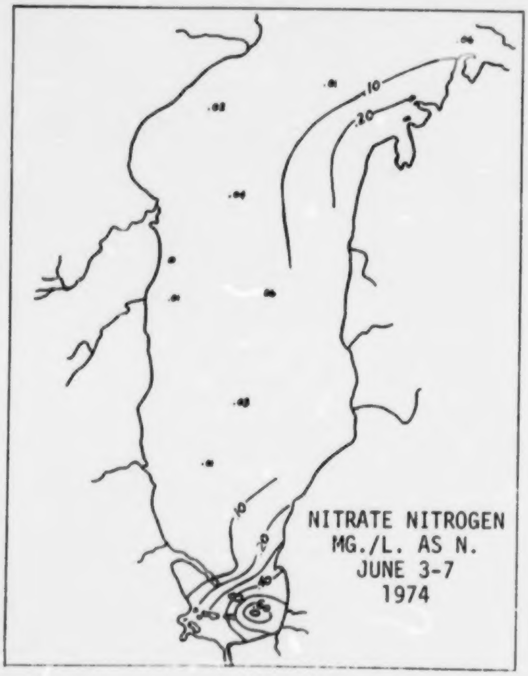
NITRITE NITROGEN
MG./L. AS N.
SEPTEMBER 4-5
1974

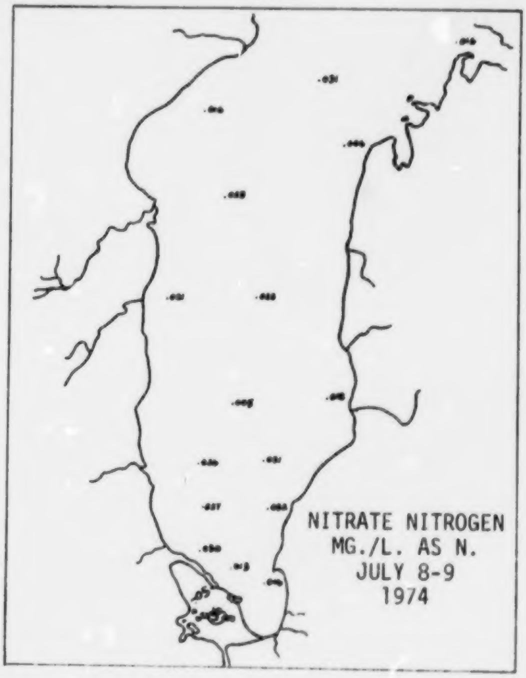
FIGURE III-15

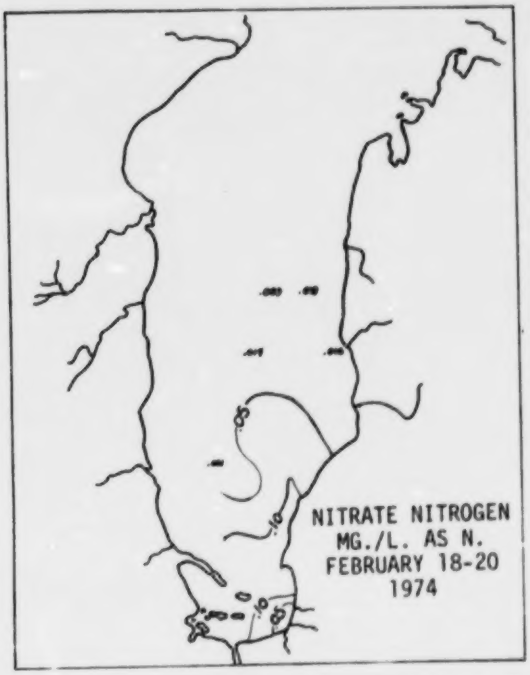
Nitrate Nitrogen Contours in Lower Green Bay

Nitrate nitrogen showed dramatic fluctuations in concentration during the study period. The July 1974 survey revealed an overall level of nitrate much lower than in any other survey. This pattern corresponds to the bloom of nitrogen-fixing algae. August and September 1974 indicated significant increases in nitrate in all locations. Some of this increase may be due to nitrogen released by nitrogen-fixing algae cells that have died and released their nitrogen. Vanderhoef, et al (1972, 1973) have suggested that 40 percent of the inorganic nitrogen contributed to the Bay during the bloom period (mid-June to mid-August) may come from nitrogen fixing algae.

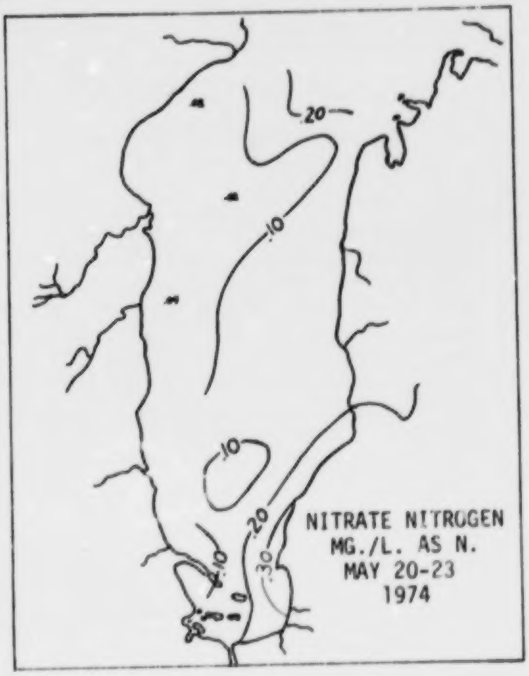

NITRATE NITROGEN
MG./L. AS N.
SEPTEMBER 24-25
1973


NITRATE NITROGEN
MG./L. AS N.
JUNE 3-7
1974

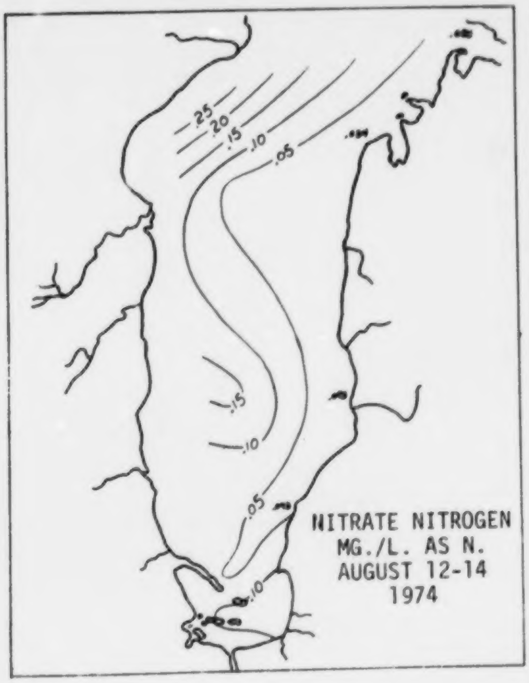

NITRATE NITROGEN
MG./L. AS N.
JULY 8-9
1974



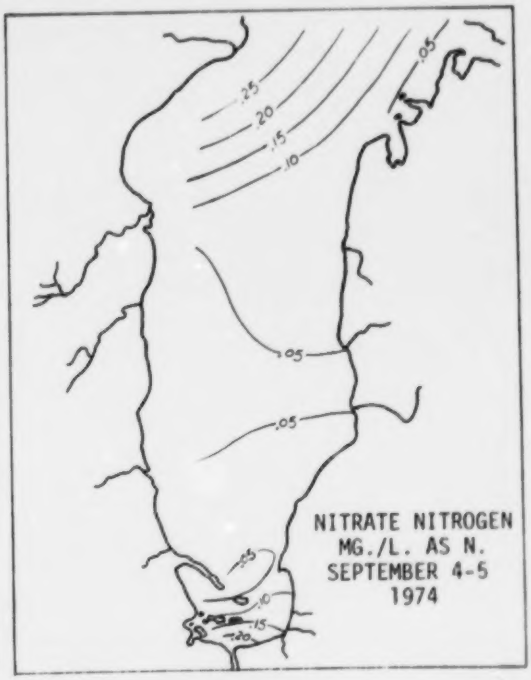
NITRATE NITROGEN
MG./L. AS N.
FEBRUARY 18-20
1974


.20
.10
.10
.20
.30
.10

NITRATE NITROGEN
MG./L. AS N.
MAY 20-23
1974


.25
.20
.15
.10
.05
.15
.10
.05
.10

NITRATE NITROGEN
MG./L. AS N.
AUGUST 12-14
1974

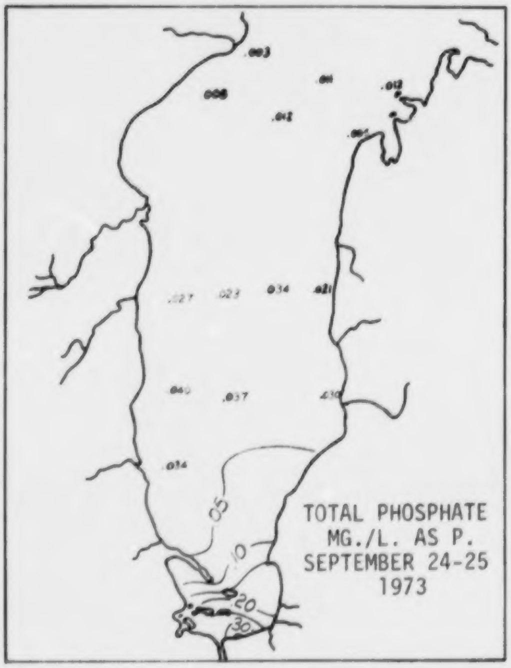

.25
.20
.15
.10
.05
.05
.05
.05
.10
.15
.20

NITRATE NITROGEN
MG./L. AS N.
SEPTEMBER 4-5
1974

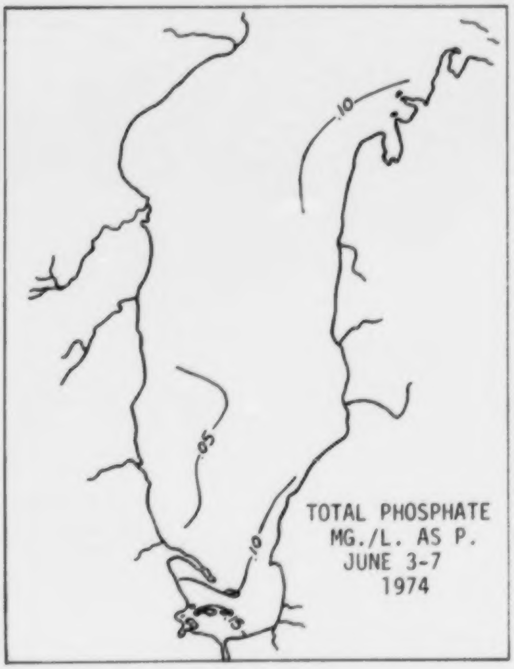
FIGURE III-16

Total Phosphorus Contours
in Lower Green Bay

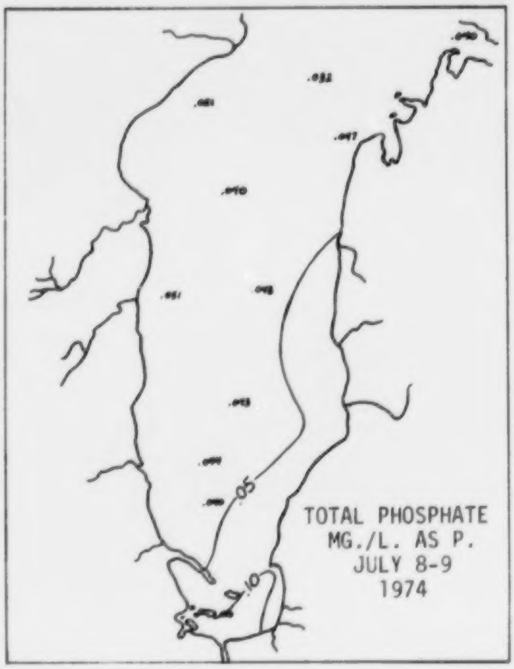
Total phosphorus did not fluctuate nearly as much as the nitrogen forms. The highest concentrations were consistently found in the Inner Bay and along the eastern half of the Bay. Significant decreases in total phosphorus concentrations occurred between the July and August 1974 surveys corresponding to the areas of the blue-green algae bloom during this period.



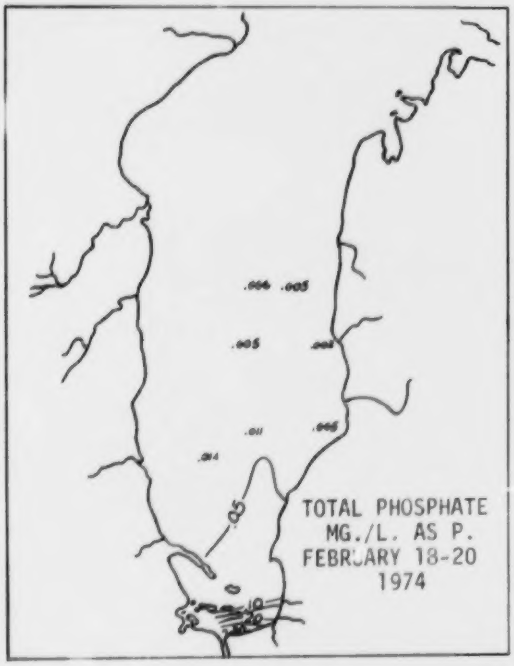
TOTAL PHOSPHATE
MG./L. AS P.
SEPTEMBER 24-25
1973



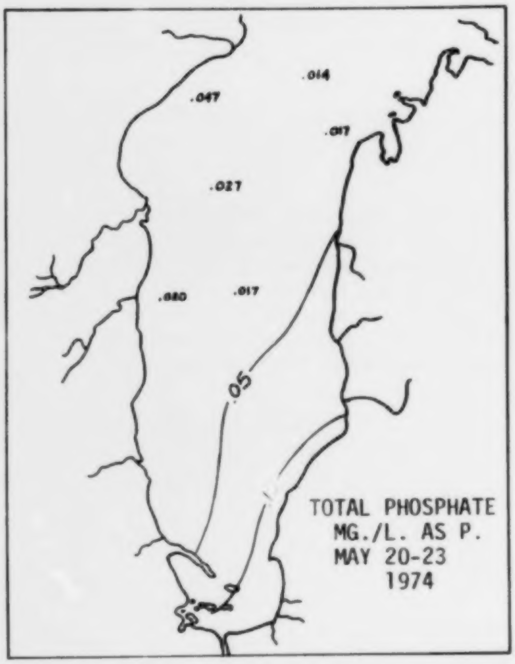
TOTAL PHOSPHATE
MG./L. AS P.
JUNE 3-7
1974



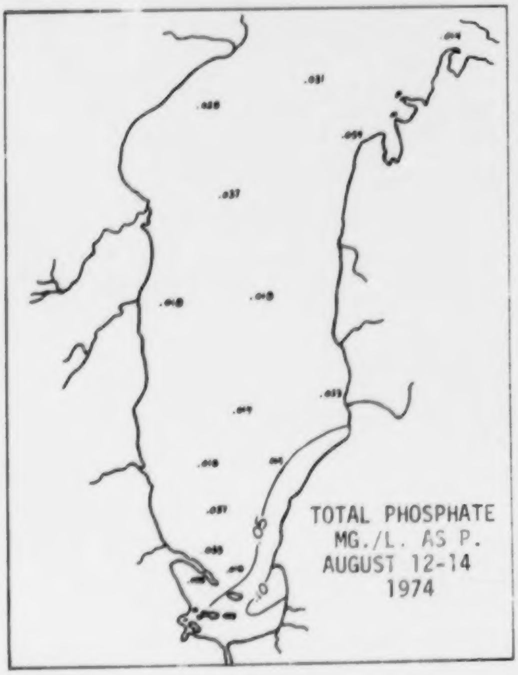
TOTAL PHOSPHATE
MG./L. AS P.
JULY 8-9
1974


.005
.005
.011
.014
.05
.10
.20

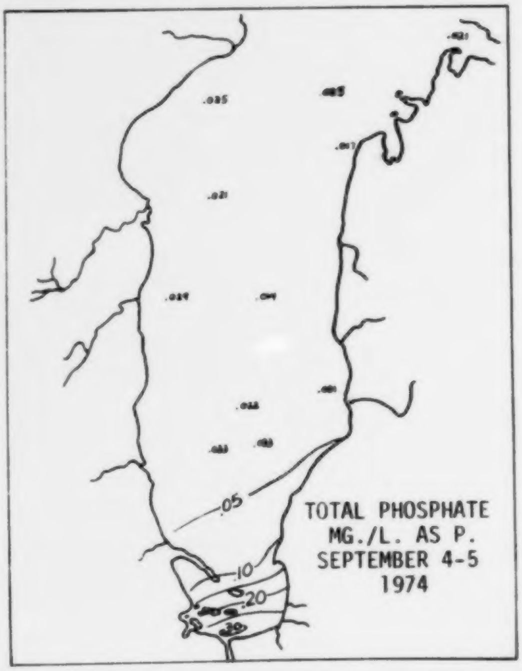
TOTAL PHOSPHATE
MG./L. AS P.
FEBRUARY 18-20
1974


.014
.047
.017
.027
.080
.017
.05

TOTAL PHOSPHATE
MG./L. AS P.
MAY 20-23
1974


.031
.037
.05
.10

TOTAL PHOSPHATE
MG./L. AS P.
AUGUST 12-14
1974

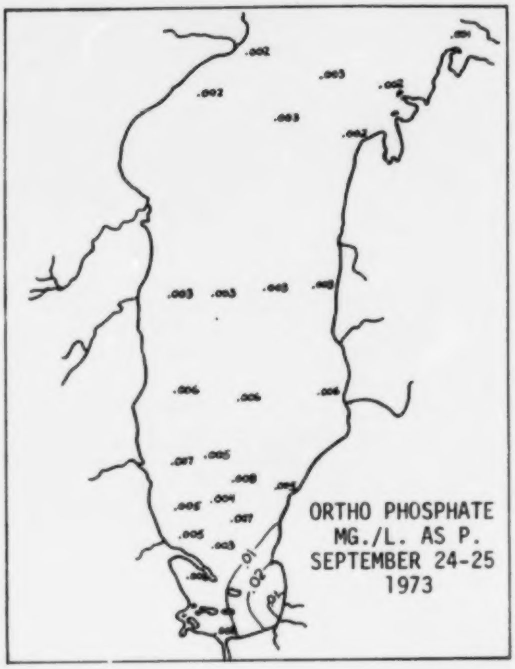

.025
.021
.05
.10
.20
.30

TOTAL PHOSPHATE
MG./L. AS P.
SEPTEMBER 4-5
1974

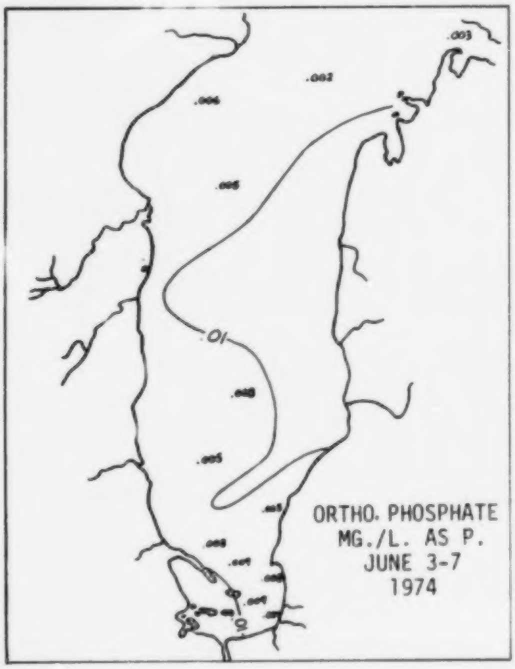
FIGURE III-17

Ortho Phosphorus Contours in Lower Green Bay

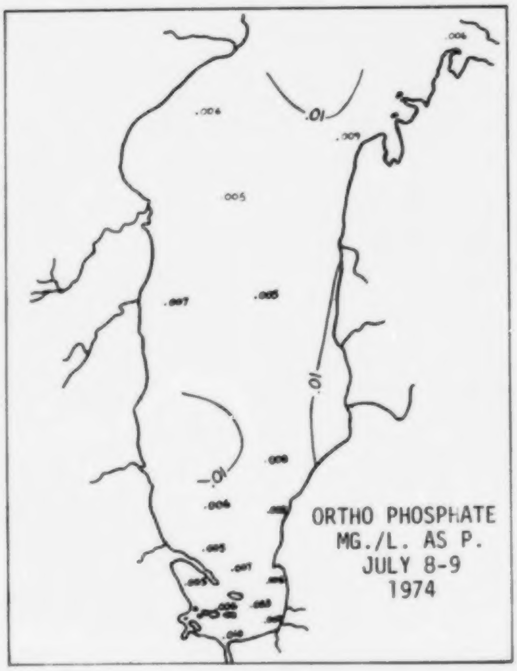
Ortho phosphorus concentrations showed a nearly steady increase from September 1973 until June 1974 at nearly all locations. During the last three surveys the concentrations fell slowly to levels comparable to the September 1973 concentrations.



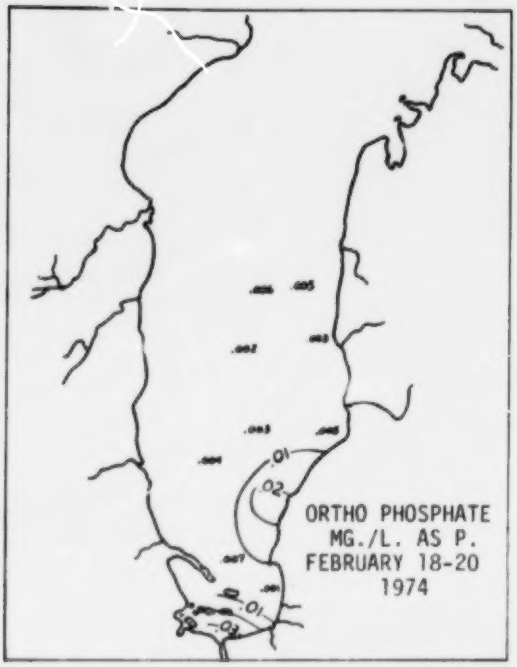
ORTHO PHOSPHATE
MG./L. AS P.
SEPTEMBER 24-25
1973



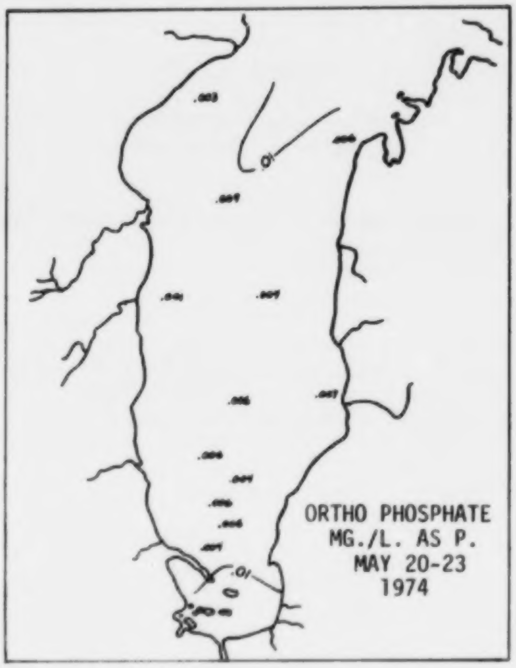
ORTHO PHOSPHATE
MG./L. AS P.
JUNE 3-7
1974



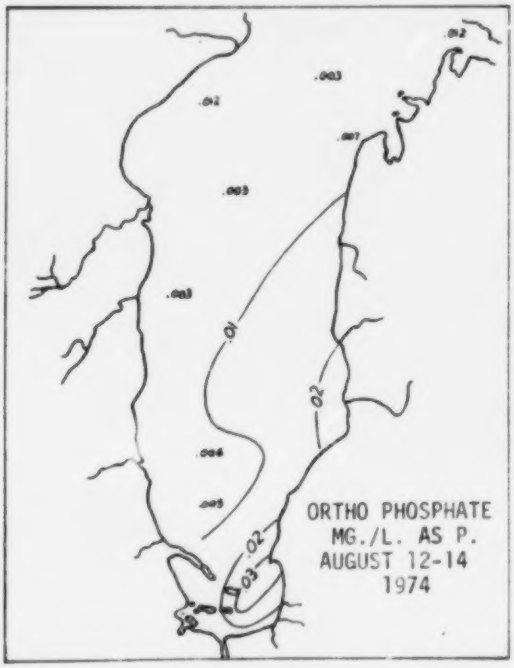
ORTHO PHOSPHATE
MG./L. AS P.
JULY 8-9
1974



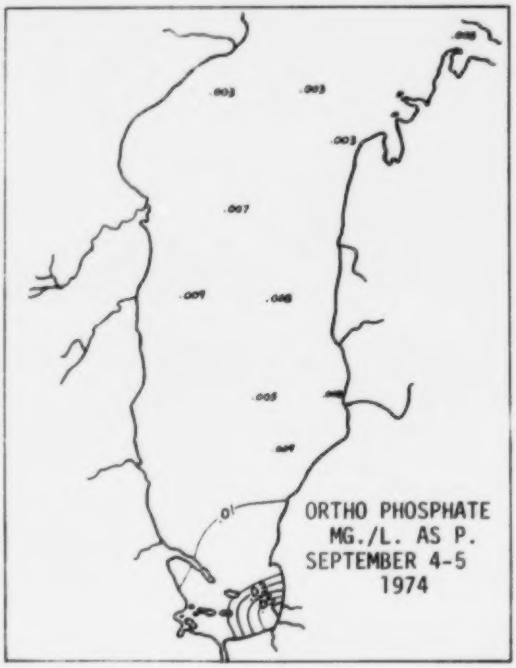
ORTHO PHOSPHATE
MG./L. AS P.
FEBRUARY 18-20
1974



ORTHO PHOSPHATE
MG./L. AS P.
MAY 20-23
1974


.012
.003
.012
.007
.003
.003
.01
.02
.004
.005
.02
.03

ORTHO PHOSPHATE
MG./L. AS P.
AUGUST 12-14
1974

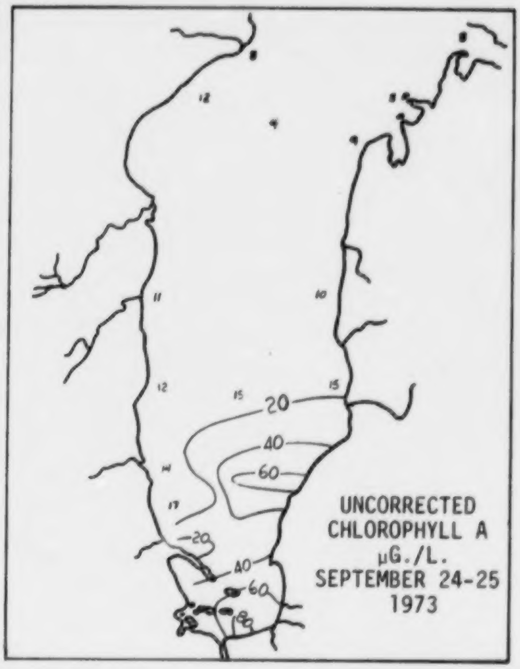

.003
.003
.003
.007
.01

ORTHO PHOSPHATE
MG./L. AS P.
SEPTEMBER 4-5
1974

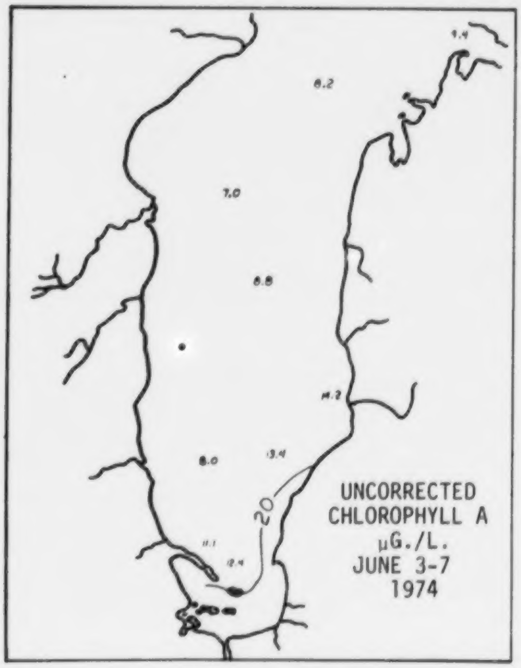
FIGURE III-18

Chlorophyll-a Contours in Lower Green Bay

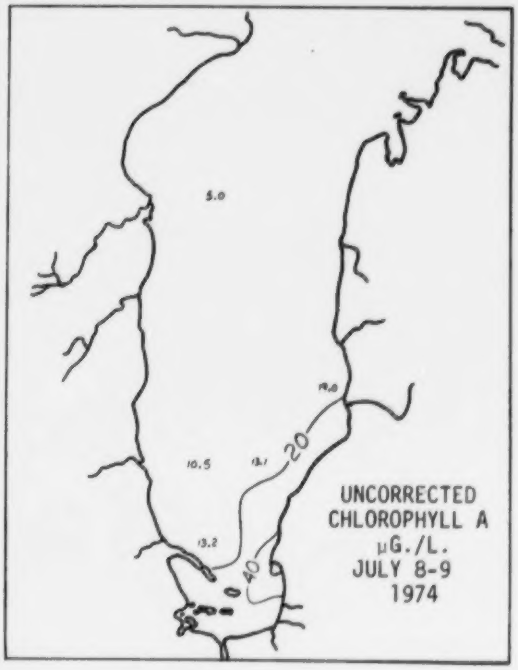
Chlorophyll-a fluctuated most markedly in the lower one-third of the study area. Both September surveys showed fairly uniform gradients of chl-a ranging from 80 µ g/l at the mouth of the Fox River to about 20 µ g/l around Dykesville. Between June and August 1974, concentrations grew steadily. Concentrations over 100.0 µ g/l were observed near the Fox River mouth during the August survey. Phaeo pigments are listed in Appendix F.


12
11
10
12
15
15
20
40
60
14
17
20
40
60
80

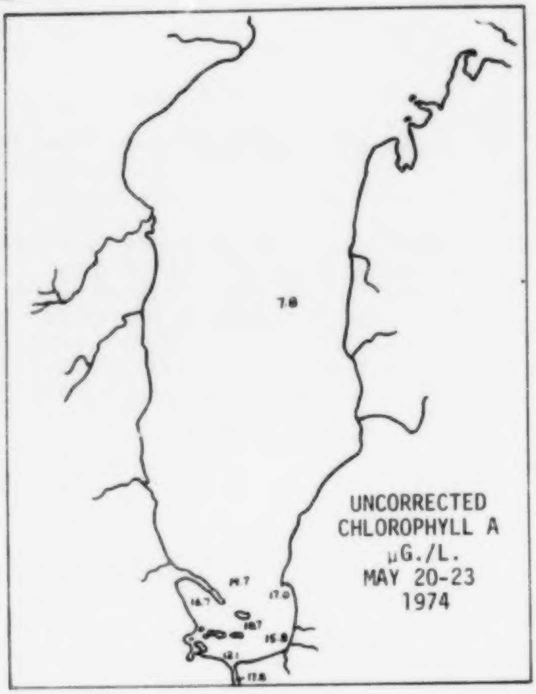
UNCORRECTED CHLOROPHYLL A µG./L. SEPTEMBER 24-25 1973


9.4
8.2
7.0
8.8
14.2
8.0
13.4
20
11.1
12.4

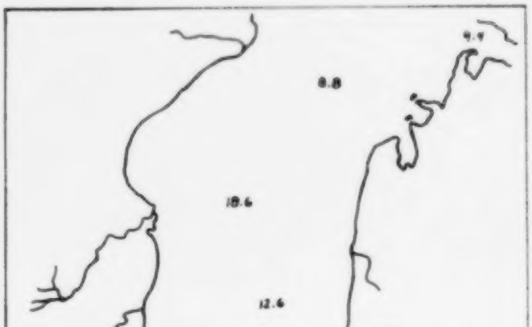
UNCORRECTED CHLOROPHYLL A µG./L. JUNE 3-7 1974


5.0
19.0
10.5
13.1
20
13.2
40

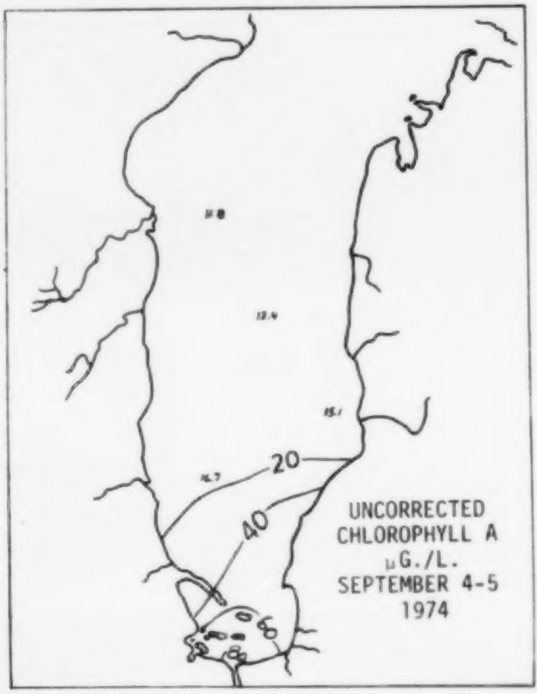
UNCORRECTED CHLOROPHYLL A µG./L. JULY 8-9 1974


7.8
14.7
16.7
17.0
18.7
15.8
18.1
17.8

UNCORRECTED
CHLOROPHYLL A
μG./L.
MAY 20-23
1974


9.9
8.8
10.6
12.6
3.9
20
40
60
20
40
60
80
100

UNCORRECTED
CHLOROPHYLL A
μG./L.
AUGUST 12-14
1974

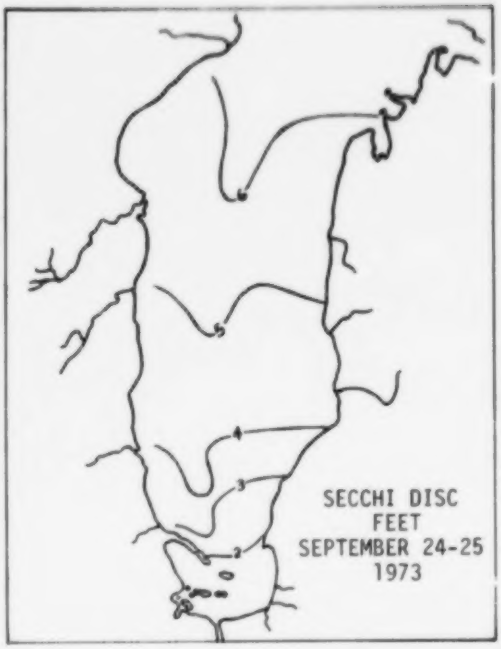

11.8
12.4
15.1
16.7
20
40
60
80

UNCORRECTED
CHLOROPHYLL A
μG./L.
SEPTEMBER 4-5
1974

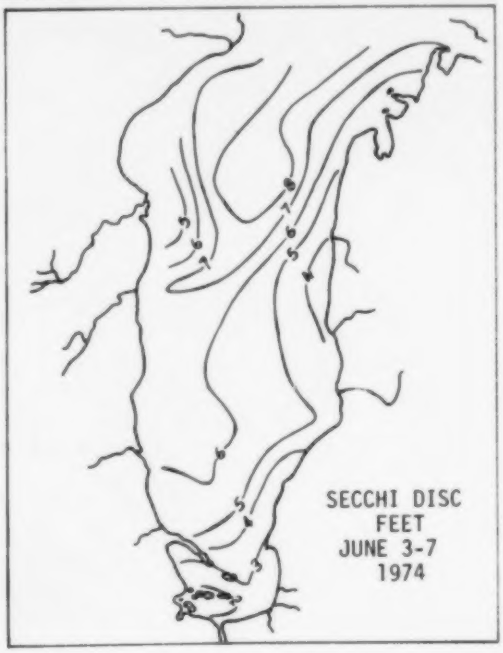
FIGURE III-19

Secchi Disc Reading in Lower Green Bay

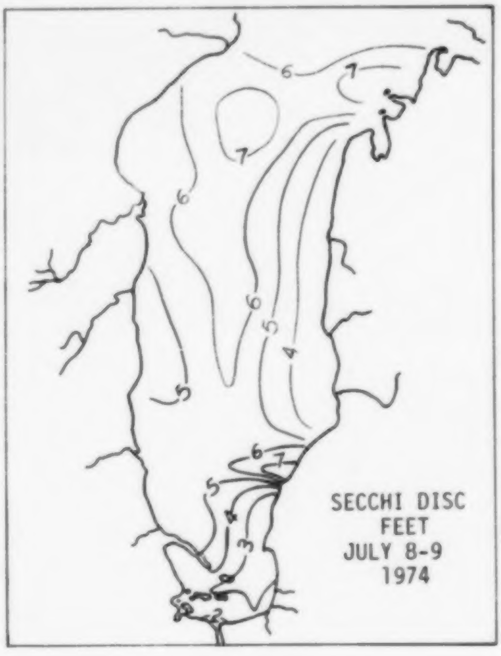
Secchi disc readings generally corresponded to the extent of the algae activity. The light penetration was consistently highest in the areas furthest from the Fox River. Light penetration of only 1 to 3 feet was consistently measured in the Inner Bay.



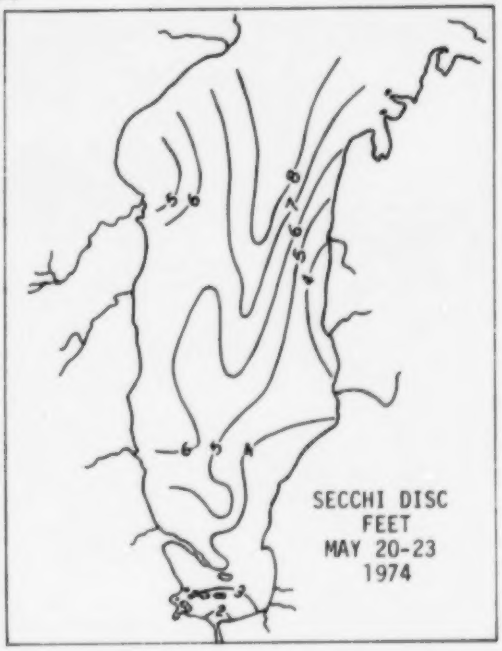
SECCHI DISC
FEET
SEPTEMBER 24-25
1973



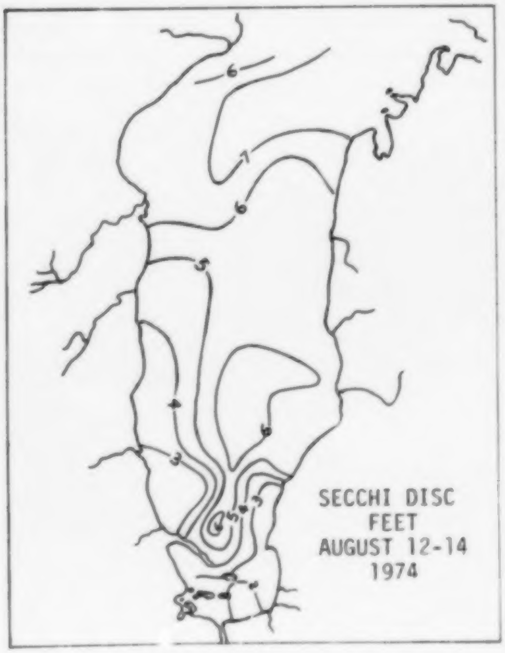
SECCHI DISC
FEET
JUNE 3-7
1974



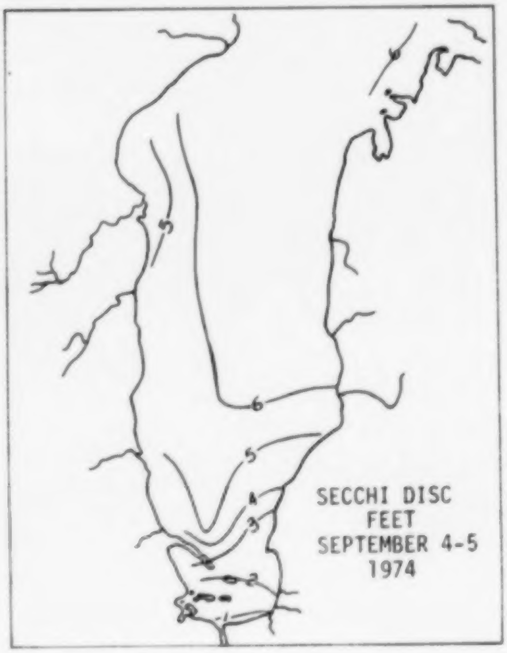
SECCHI DISC
FEET
JULY 8-9
1974


5
6
8
7
6
5
4
6
5
4
3
2

SECCHI DISC
FEET
MAY 20-23
1974



SECCHI DISC
FEET
AUGUST 12-14
1974

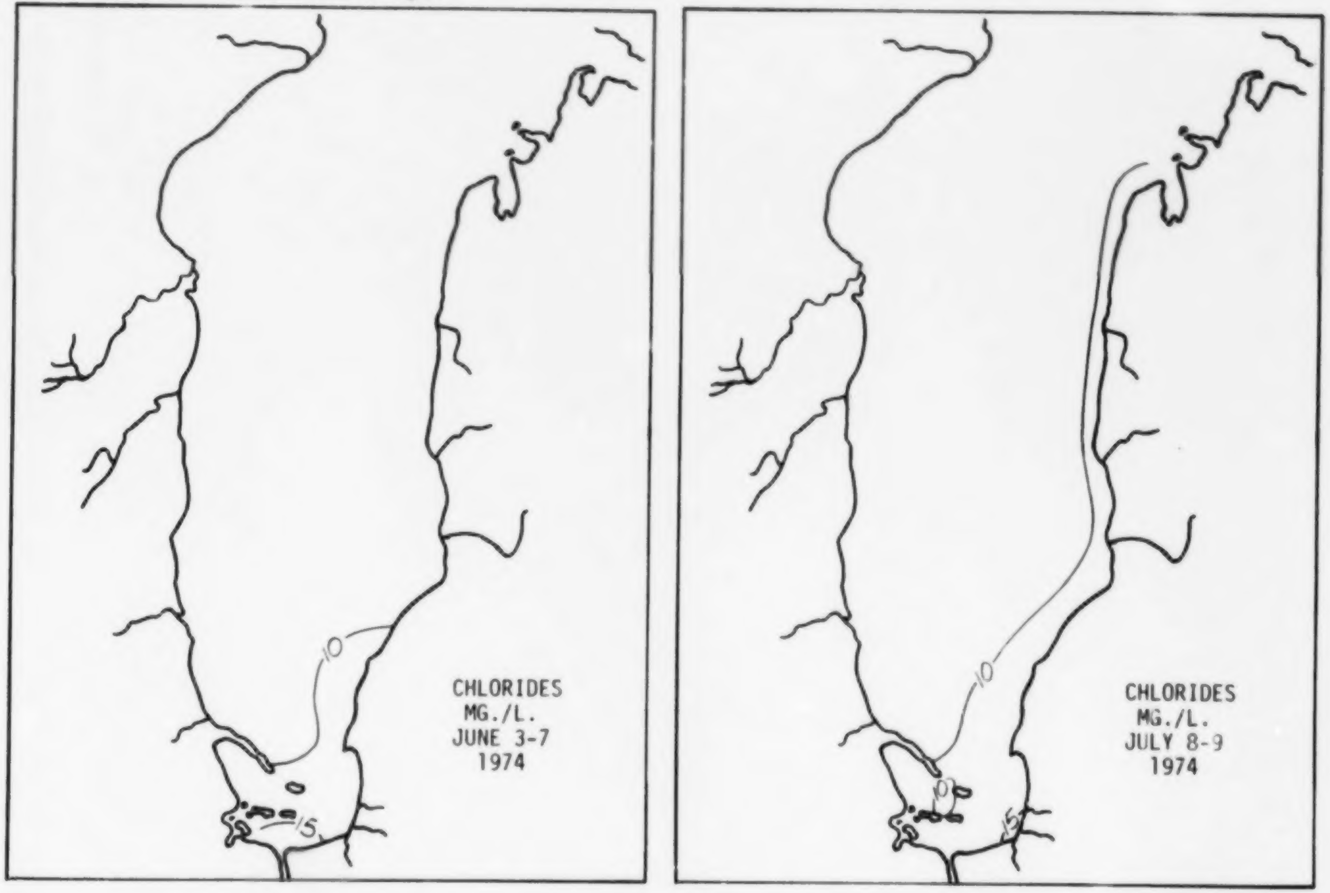


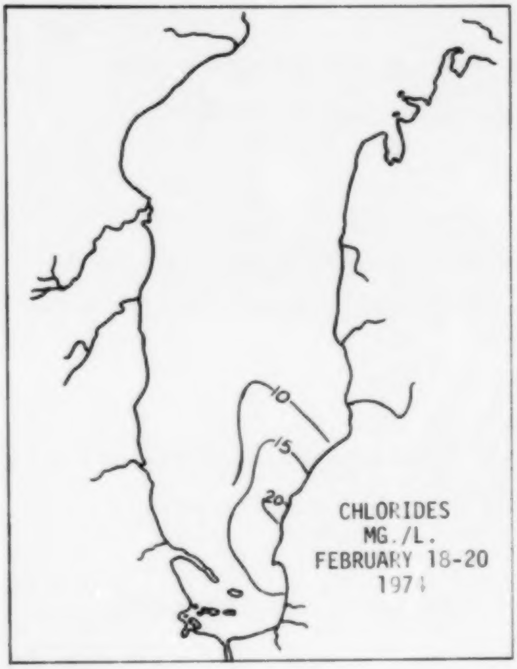
SECCHI DISC
FEET
SEPTEMBER 4-5
1974

FIGURE III-20

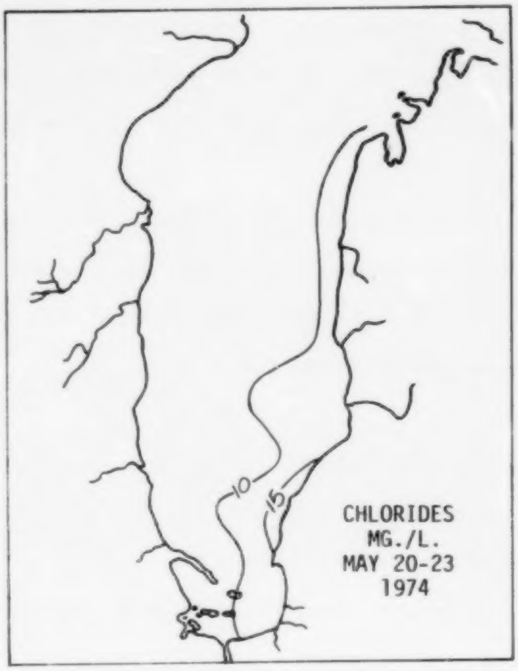
Chloride Contours in Lower Green Bay

Chloride concentration appeared to be relatively stable in the Lower Bay. Concentration gradients ranging from 25 mg/l at the Fox River mouth to less than 10 mg/l further nor appear in nearly all surveys.

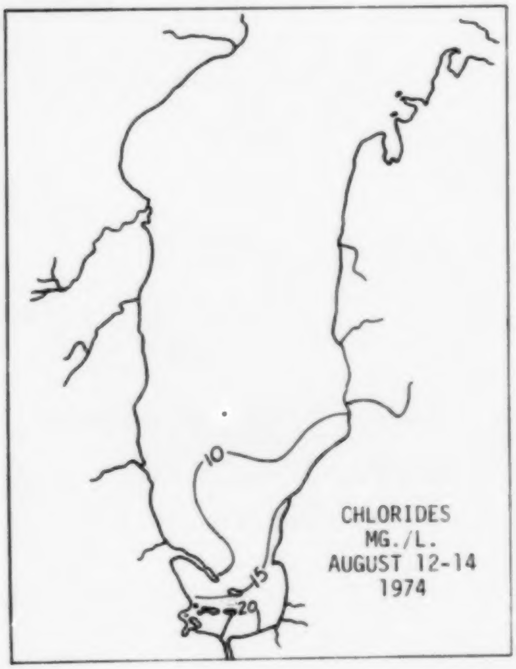

10
15
CHLORIDES
MG./L.
JUNE 3-7
1974
10
10
15
CHLORIDES
MG./L.
JULY 8-9
1974



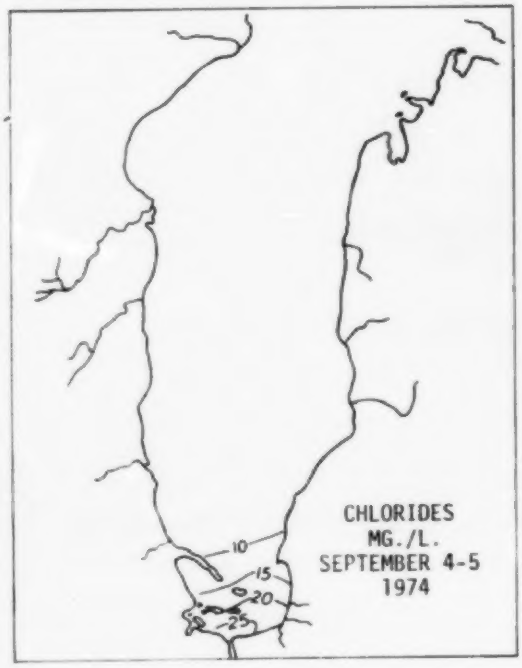
CHLORIDES
MG./L.
FEBRUARY 18-20
1974



CHLORIDES
MG./L.
MAY 20-23
1974



CHLORIDES
MG./L.
AUGUST 12-14
1974



CHLORIDES
MG./L.
SEPTEMBER 4-5
1974

the Red Banks area. In all surveys the concentrations dropped off sharply with distance from the Fox River. Concentrations below 20 ug/l and usually below 10 ug/l were found north of a line from Dykesville to the Little Suamico River.

It is interesting to note that the percent of the chlorophyll-a that is phaeo-pigments (inactive chlorophyll-a from dead algae) increased throughout the summer. In August for example, in the Inner Bay, phaeo-pigments comprised nearly 50% of the measured chlorophyll-a.

Algae: The purpose of the study was to collect a background of information concerning the principal types of planktonic algae in the lower third of Green Bay, to be used as a starting point for further studies and monitoring. This includes a Biomass estimate, a qualitative analysis of algae present and distribution patterns of dominant algae.

The following is a qualitative report of observations obtained in the spring and summer surveys and a description of schematic representation of the dominant algae at each station based on the number of occurrences. (See Figures III-21 through III-25)

Winter 1974 (No figure included)

Limited sampling done through the ice at only two stations in the Lower Bay showed a predominance of diatoms. Most common were Asterionella, Cyclotella and Fragilaria. Species of Oscillatoria, rotifers and a few Chlorophyta were also present. The diatoms constituted about 70-90% of the algae flora.

May 20-23 (Figure III-21)

A variety of diatoms predominated at most of the sampling stations. There was a sizeable increase in numbers compared to the winter sample. The most common genera were *Asterionella*, *Cyclotella*, *Stephanodiscus*, *Fragilaria* and now *Melosira*. These organisms were distributed over the entire lower third of the Bay and may represent the later stages of a diatom bloom as described by Wiersma 1974 as a spring peak in April and tapering off in May.

It was interesting to note that *Melosira* was the dominant organism at the mouth of the Lower Fox River, a condition that persisted throughout the summer. Species of green algae, mostly of the genera *Scenedesmus* and *Ankistrodesmus*, predominated in the Lower Bay along the eastern shoreline. *Ankistrodesmus* along with *Oscillatoria* and diatoms predominated at stations, far from the Lower Fox River. Small concentrations of *Microcystis* and *Anabaena* occurred at stations below the Red River-Little Suamico River transect. *Cyclotella* and *Stephanodiscus* were the outstanding diatoms in the indicated areas.

June 3-5 (Figure III-22)

A large increase in the variety of green algae and numbers of *Oscillatoria* and diatoms occurred in June. *Melosira* and green algae dominated in the region below Long Tail Point. *Oscillatoria* and diatoms dominated above Long Tail Point. *Scenedesmus* and several other species of green algae were concentrated along the eastern shoreline as far as Red Banks.

July 8-9 (Figure III-23)

A bloom of algae occurred after the first week of June. The bloom extended over the entire sampling area of the Bay. Blue-green algae dominated this bloom. The most common genus was Aphanizomenon, except for stations 1 and 2 where Melosira predominated. At stations 17, 31 and 43, (above Long Tail Point) species of Oscillatoria predominated. The diatoms Cyclotella and Stephanodiscus were common but not dominant at station 43, the furthest sampling station from the mouth of the Lower Fox River. A variety of green algae persisted at some stations in the Lower Bay and zooplankton concentrations were larger than in prior surveys.

August 12-13 (Figure III-24)

Bloom conditions continued to persist over the entire sampling area. The extent of the bloom beyond Sturgeon Bay was not investigated. The dominant organism at all stations beyond Long Tail Point was Oscillatoria with heavy concentrations of Aphanizomenon near Sturgeon Bay and along the eastern shoreline below Renard River. Melosira continued to predominate in the Lower Fox River. Microcystis was also abundant in the Lower Fox River. Heavy concentrations of Melosira occurred throughout the Lower Bay as far north as the Red River. Genera of blue-green algae (Microcystis, Anabaena, etc.) occurred throughout the entire Bay. The heaviest concentrations appeared within the Lower Bay below the Point Sable-Long Tail Point barrier and along the eastern shore to Red Banks. Green algae appeared most commonly along the eastern shoreline from below Point Sable to Red Banks. A greater number of the Dinoflagellates, most notably Ceratium, appeared in the upper stations. Greater concentrations of zooplankton than previously observed occurred at all stations in the Bay, especially in the upper most region.

September 4-5 (Figure III-25)

A second bloom of Aphanizomenon occurred although not as extensively as the bloom which began in mid-June, lasting through August. Bloom conditions persisted throughout the Bay. In the upper regions of the sampling area Oscillatoria was the dominant organism. A noticeable increase in the concentration of the diatom Asterionella occurred at these upper stations.

Areas of highest concentration of Aphanizomenon occurred in the Inner Bay and above Long Tail Point on the western side of the Bay up to the Little Suamico River, where it dominated the community, an area which previously was dominated by diatoms and Oscillatoria. The eastern shoreline below the Red River and the Inner Bay was a massive mixture of many organisms dominated by Aphanizomenon, Microcystis, Melosira, green algae, Oscillatoria and zooplankton. This condition extended beyond the Long Tail Point-Point Sable barrier to a transect from the Little Suamico River to the Red River.

Summary of Survey Observations

Heavy growths of algae were present in Green Bay when intensive sampling began in late May. Large blooms occurred by mid-June and continued through early September when sampling was discontinued. By September "pea soup" conditions prevailed in the Lower Bay and extensive blooms reached the upper regions of the lower third of the Bay. Field workers described the Bay as "the worst they've ever seen it."

FIGURE III-21

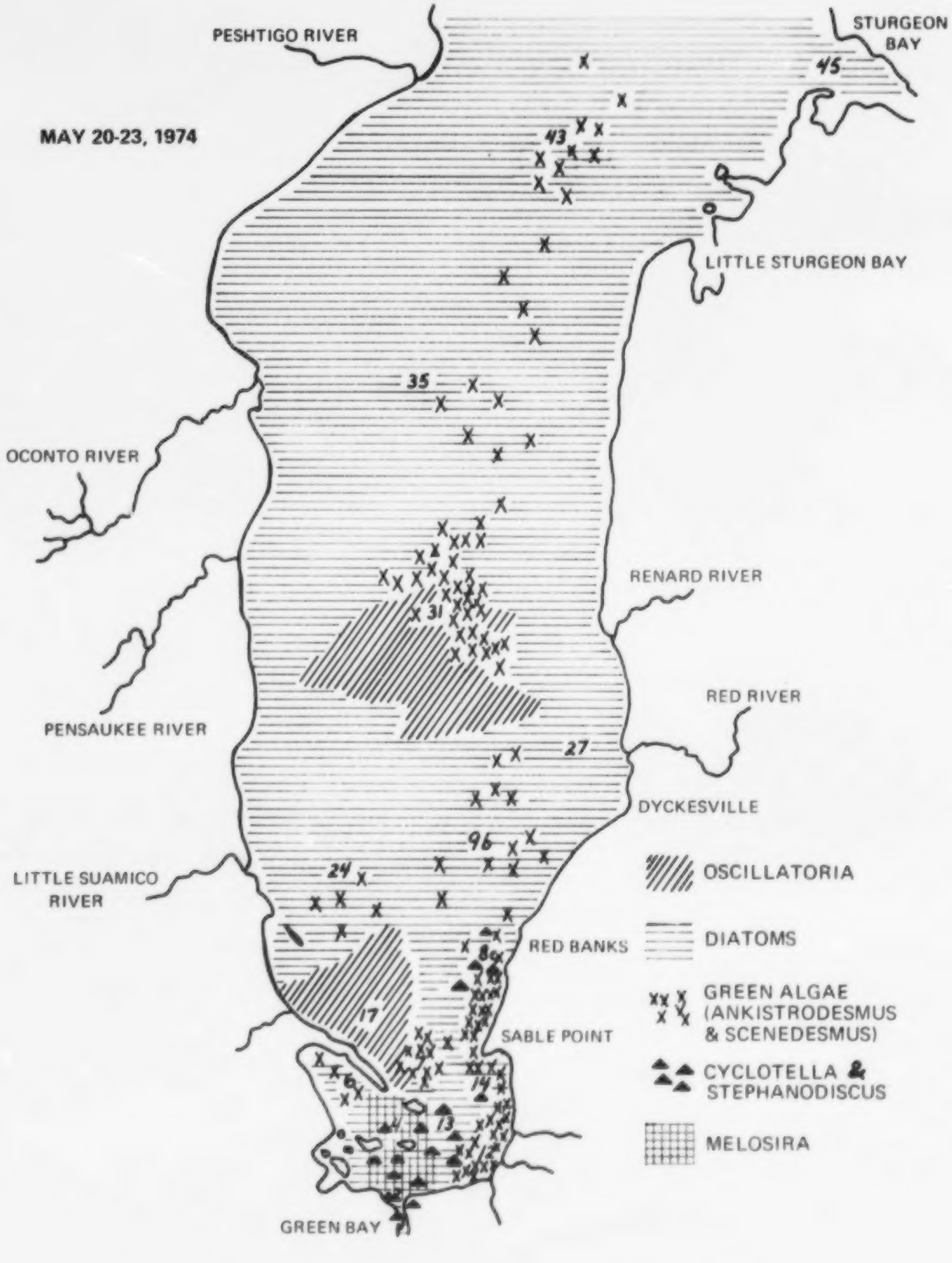
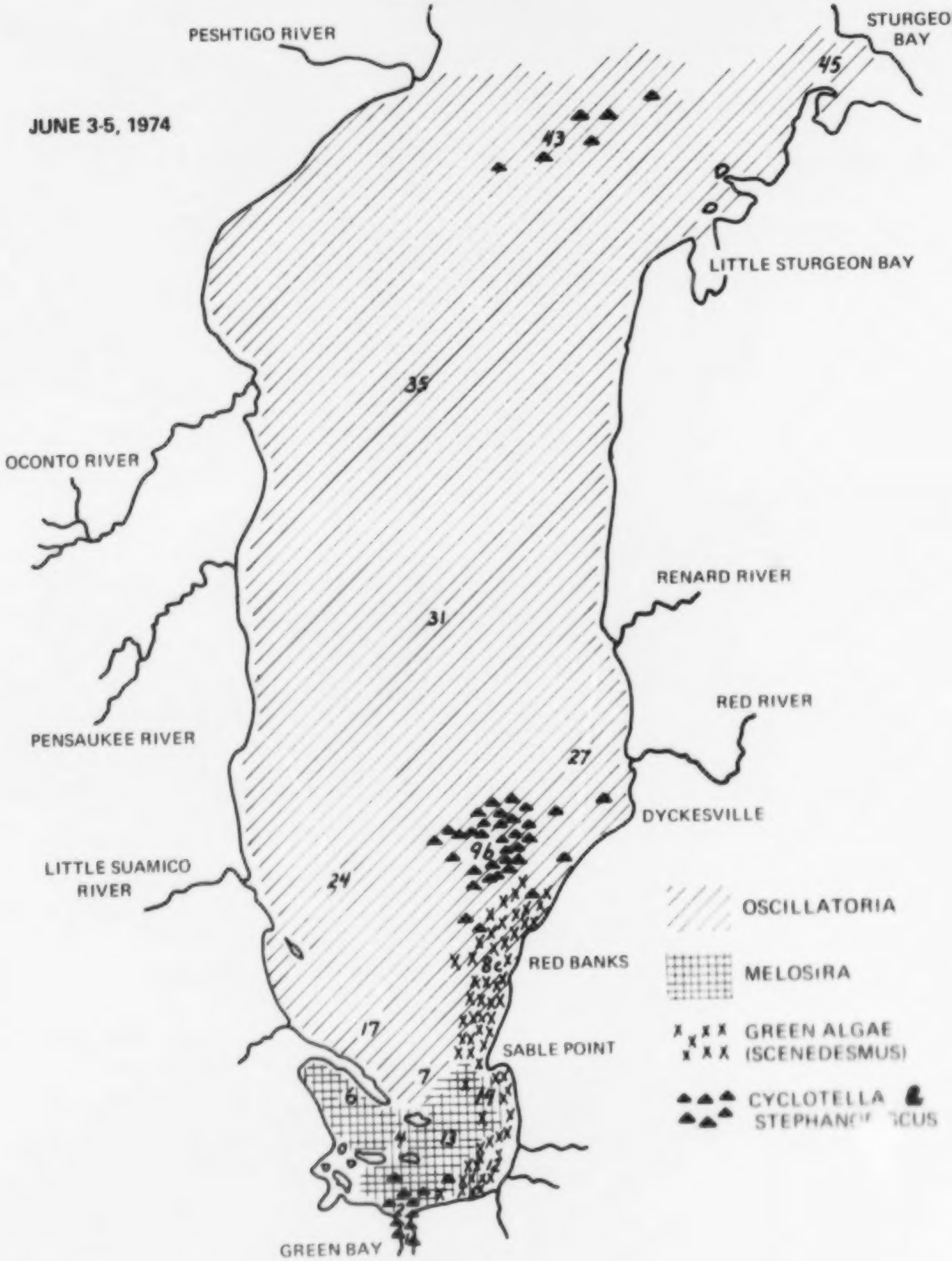

PESHTIGO RIVER
STURGEON BAY
45
MAY 20-23, 1974
43
LITTLE STURGEON BAY
35
OCONTO RIVER
RENARD RIVER
31
RED RIVER
PENSAUKEE RIVER
27
DYCKESVILLE
96
24
LITTLE SUAMICO RIVER
OSCILLATORIA
RED BANKS
DIATOMS
8
GREEN ALGAE (ANKISTRODESMUS & SCENEDESMUS)
17
SABLE POINT
6
14
CYCLOTELLA & STEPHANODISCUS
13
MELOSIRA
GREEN BAY

FIGURE III–22



JUNE 3-5, 1974

PESHTIGO RIVER
STURGEON BAY
45
43
LITTLE STURGEON BAY
35
OCONTO RIVER
RENARD RIVER
31
PENSAUKEE RIVER
RED RIVER
27
DYCKESVILLE
9b
LITTLE SUAMICO RIVER
24
RED BANKS
8c
17
SABLE POINT
7
6
14
4
13
12
GREEN BAY
OSCILLATORIA
MELOSIRA
GREEN ALGAE (SCENEDESMUS)
CYCLOTELLA & STEPHANO SCUS

FIGURE III–23

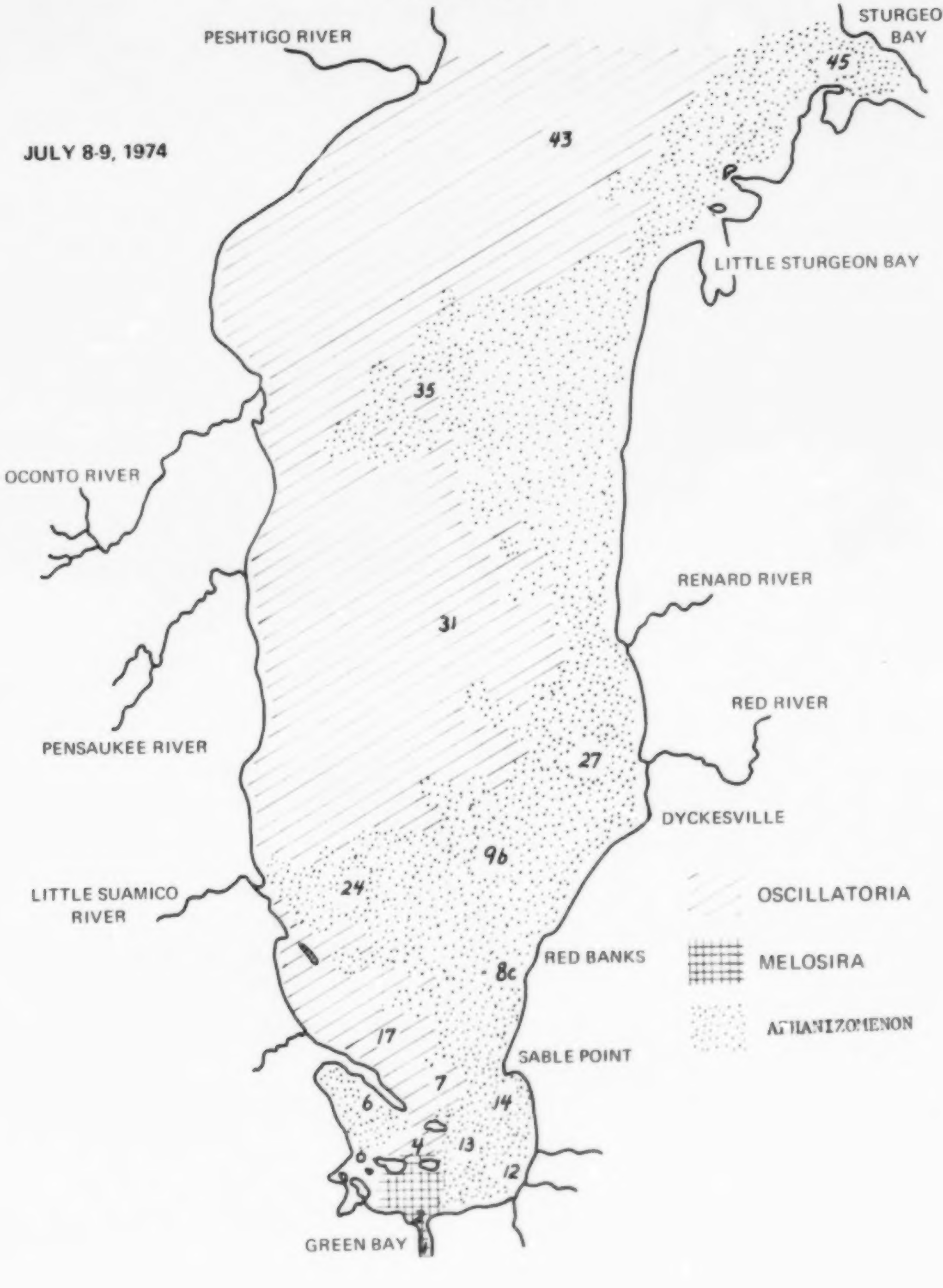
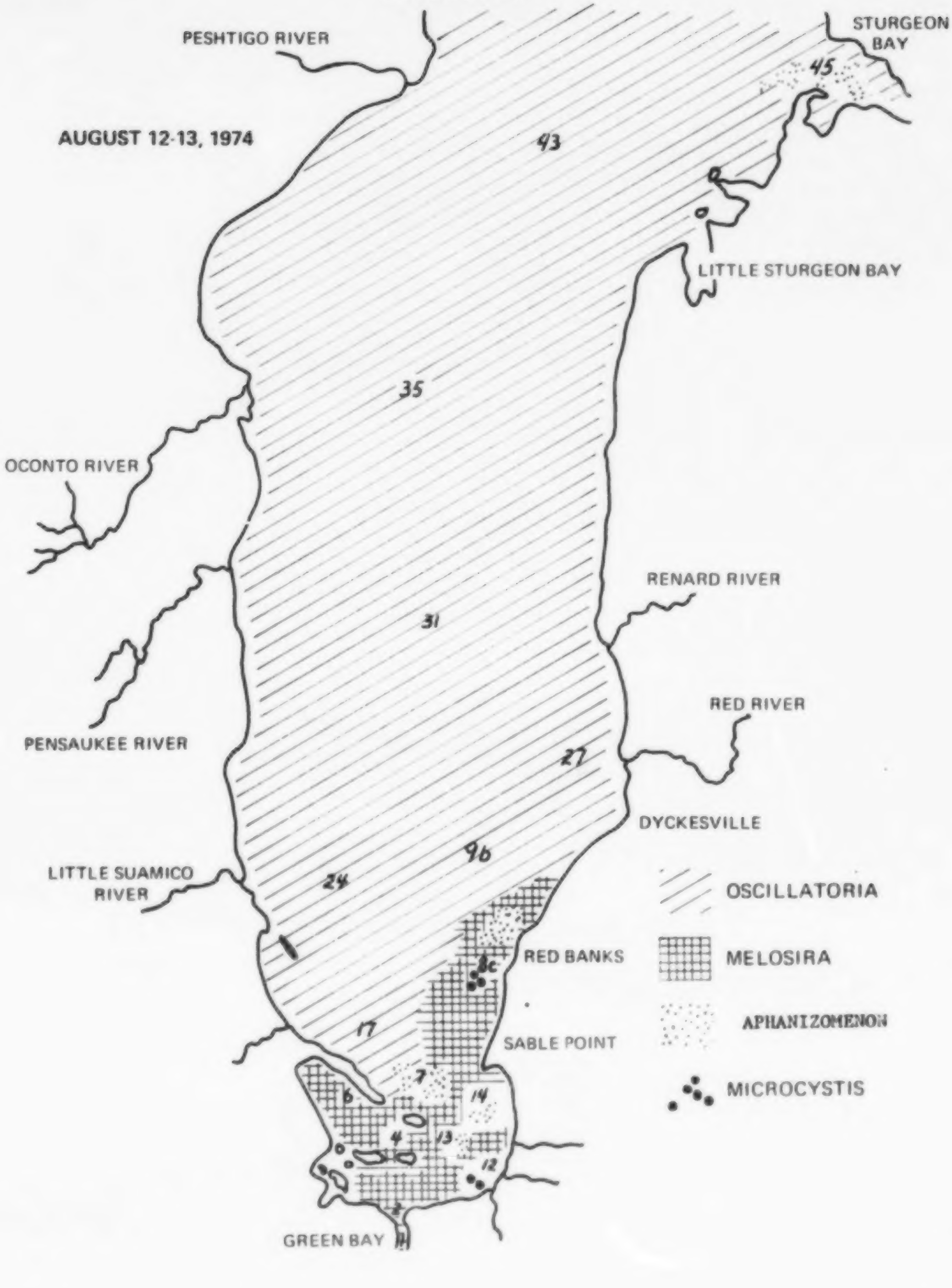
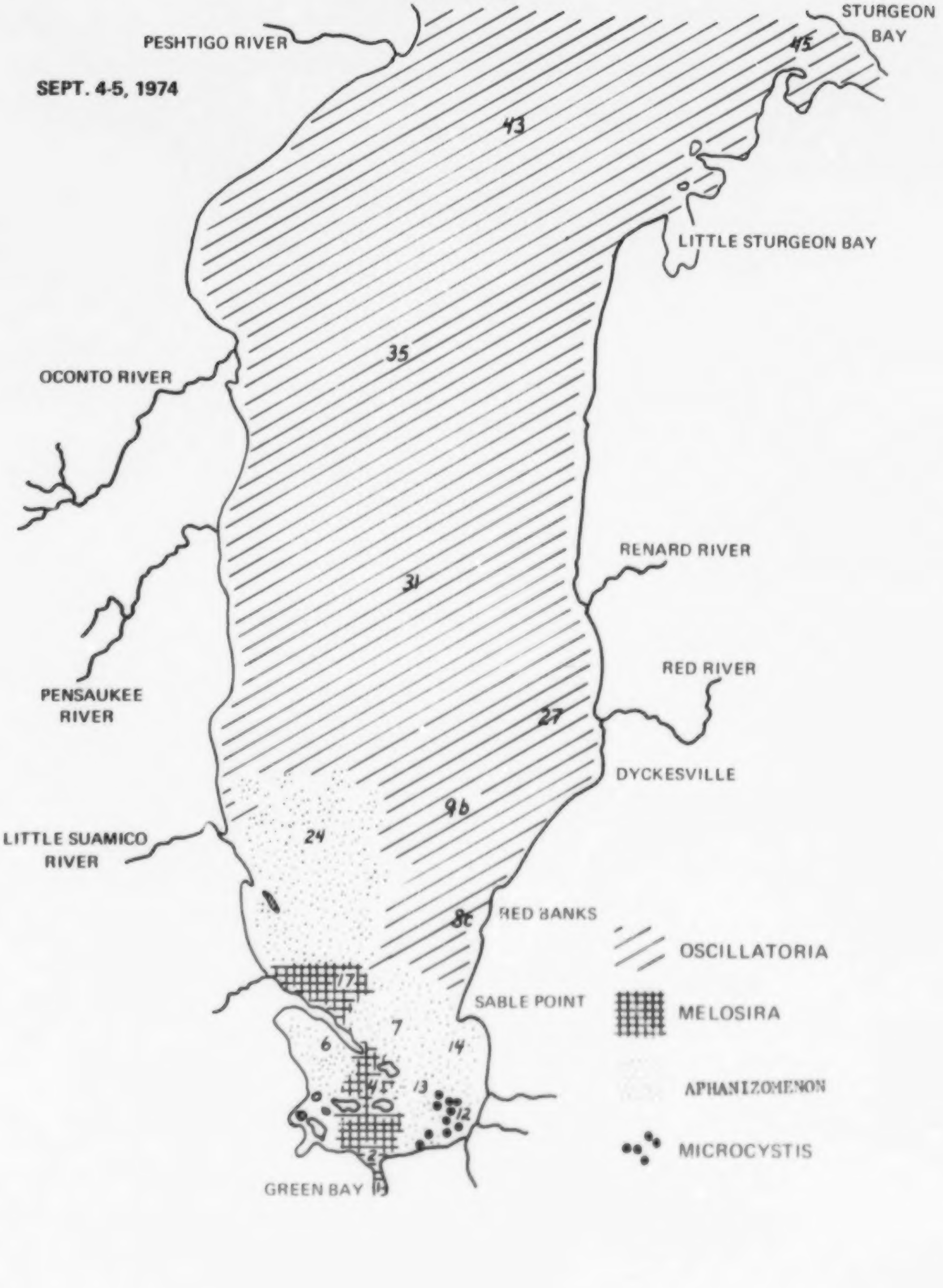

JULY 8-9, 1974
PESHTIGO RIVER
STURGEON BAY
45
43
LITTLE STURGEON BAY
35
OCONTO RIVER
RENARD RIVER
31
PENSAUKEE RIVER
RED RIVER
27
DYCKESVILLE
9b
LITTLE SUAMICO RIVER
24
RED BANKS
8c
17
SABLE POINT
7
6
14
13
4
12
2
1
GREEN BAY
OSCILLATORIA
MELOSIRA
APHANIZOMENON

FIGURE III–24


PESHTIGO RIVER
STURGEON BAY
45
43
LITTLE STURGEON BAY
35
OCONTO RIVER
RENARD RIVER
31
RED RIVER
PENSAUKEE RIVER
27
DYCKESVILLE
9b
LITTLE SUAMICO RIVER
24
RED BANKS
8c
SABLE POINT
17
7
6
14
4
13
12
2
GREEN BAY
OSCILLATORIA
MELOSIRA
APHANIZOMENON
MICROCYSTIS

AUGUST 12-13, 1974

FIGURE III-25


SEPT. 4-5, 1974
PESHTIGO RIVER
STURGEON BAY
45
43
LITTLE STURGEON BAY
35
OCONTO RIVER
31
RENARD RIVER
PENSAUKEE RIVER
RED RIVER
27
DYCKESVILLE
9b
24
LITTLE SUAMICO RIVER
8c
RED BANKS
17
SABLE POINT
7
6
14
4s
13
12
2
GREEN BAY
1
OSCILLATORIA
MELOSIRA
APHANIZOMENON
MICROCYSTIS

A variety of algae and zooplankton predominated at different times throughout the summer. Most prominent of these were the blue-green algae Aphanizomenon, Oscillatoria and Microcystis; the diatoms Melosira, Cyclotella, Stephanodiscus and Asterionella; the green algae Scenedesmus and Ankistrodesmus; Dinoflagellates, Ceratium and the zooplankters Cladocerans, copepods and rotifers.

Discussion

The relationship between the principal algae tabulated in Table III-3 to one another at each station at a given time is the basis for determining the dominate algae and the distribution patterns. This does not imply that the dominant algae is necessarily the most important in the community, but that it occurred most frequently. No attempt was made to determine the total algal community or standing crop from these counts. Comparison of the data from May and June to the July, August, September sampling cannot be done because of the different methods of sampling used. It was not possible at this time to correlate these two methods.

Wiersma (1974) has shown which algae comprise the plankton of that part of lower Green Bay within the Long Tail Point-Point Sable barrier. This survey attempted to investigate the characteristics of that portion beyond Long Tail Point as far out as Sturgeon Bay in addition to the Inner Bay.

The distribution patterns assume a continuous distribution at the 1 to 2 meter level, but do not take into account the vertical distribution. It is not known at this time what effect this would have on these patterns, especially the buoyant blue-green algae. The effects of wind and currents generally contribute to the concentrations of algal masses along the eastern shore. This condition extended as far as Sturgeon Bay where abundant concentrations of *Aphanizomenon* were observed. Modlin and Beeton (1970) and Sager and Wiersma (1972) observed that currents from the Fox River flow along the south and eastern shorelines of the Inner Bay and beyond Point Sable along the eastern shoreline for some distance causing concentrations of algae in this area.

At all stations sampled on Green Bay *Melosira granulata* was found in abundant concentrations at one time or more throughout the season. It attains a peak in June and a second, generally lesser, peak in August. Holland (1968) found this to be the case at sample stations in the vicinity of our stations 27, 37, 43. The other diatoms did not appear to demonstrate this characteristic. *Melosira granulata* was found to be very abundant in the mouth of the lower Fox River (station 1) throughout the entire season. Here it appears to have gained complete dominance of the community offering excessive competition thereby contributing to the exclusion of other algae during periods of bloom.

The distribution of the blue-green algae *Aphanizomenon* correlates fairly well with the distribution information reported by Vanderhoef (1972) except that we observed abundant *Aphanizomenon* concentrations farther out into the Bay than he did. (See Figure III-23) It appears as though this may be an increase in the abundance and spread of the organism, but it may be a "normal" fluctuation in the population. Further studies and monitoring will be needed to determine if this is the case.

When the Chlorophyll-A data is segregated according to the zones shown in Figure III-1, the averages show a correlation to the Chlorophyll-a data of Wiersma (1974) taken in 1973. The data shown for the zones above Long Tail Point generally indicate lower Chlorophyll-a than for the Inner Bay zone (see Table III-4). Indications are from this study that the biomass for May and June show trends that correlates with the trends of Chlorophyll-a.

Biomass data for July, August and September are unreliable and cannot be used.

TABLE III-2

Genera of Algae Observed*

CHLOROPHYTA (Green Algae)	Counting Unit
Actinastrum Hantzschii	single cell
Agmenellum sp.	colony
Ankistrodesmus falcatus	single cell
Chlorella ellipsoidea	single cell
Closteriopsis sp.	single cell
Coelastrum sp.	colony
Crucigenia sp.	colony
Dictyosperium pulchellum	single cell
Dictyosperium sp.	single cell
Echinosphaerella limnetica	single cell
Euglena acus	single cell
Euglena elastica	single cell
Golenkinia sp.	single cell
Hydrodictyon reticulatum	colony
Kirchinella sp.	colony
Micractinium pusillum	single cells
Oocystis sp.	single cell
Palmella sp.	colony
Pediastrum sp.	colony
Scenedesmus acuminatus	single cells
Scenedesmus dimorphus	single cells
Schroederia sp.	single cell
Selenastrum gracile	colony
Selenastrum sp.	colony
Tetradron trigonum	single cell
Tetradron sp.	single cell
Tetrastrum sp.	single cells
Westella sp.	colony
Zygnema sp.	filament
DESMIDS	
Closterium sp.	single cell
Staurastrum sp.	single cell
Cosmarium reniforme	single cell
CYANOPHYTA (Blue-green Algae)	
Anabaena circinalis	filament
Anabaena incenta	filament
Anabaena spiroides	filament
Anabaena flos-aquae	filament
Aphanizomenon flos-aquae	filament
Aphanocapsa sp.	colony
Chroococcus sp.	single cell
Coelospherium sp.	colony
Gomphospheria sp.	colony (av. size 0.1 mm^2)

Lyngbya bergei	filament
Lyngbya limnetica	filament
Lyngbya versicolar	filament
Microcystis aeruginosa	colony (av. size $0.7\ mm^2$)
Oscillatoria limnetica	filament
Oscillatoria subrevis	filament
Oscillatoria tenuis	filament
Oscillatoria sp.	filament
Phormidium uncinatum	filament
Phormidium sp.	filament

BACILLARIOPHYCEAE (diatoms)

Asterionella formosa	frustule
Cyclotella glomerata	frustule
Cyclotella sp.	frustule
Fragilaria crotonensis	frustule
Fragilaria sp.	frustule
Melosira binderana	filament
Melosira granulata	filament
Melosira sp.	filament
Stephanodiscus sp.	frustule
Synedra sp.	frustule
Tabularia fenestrata	frustule
Navicula sp.	frustule

DINOFLAGELLATES

Ceratium berundinella	single cell
Peridinium sp.	single cell
Dinobryon sp.	colony

ZOOPLANKTON

Cladocerans	single cell
Copepods	single cell
Rotifers	single cell

*This table represents the algal organisms observed and does not necessarily mean they were counted as they may have occurred outside of the counting grid. Where possible, identification was tentatively carried out to species. Single celled green algae unable to be identified were tentatively grouped in the Order Chlorococcales, and filamentous green algae unable to be identified were tentatively grouped in the Order Ulotrichales.

TABLE III-3

Algae Counts

	Sta. 1					Sta. 2					Sta. 4				
	May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.
Melosira[1]	140	276	Omitted (Meter malfunction)	615	432	188	188	Omitted (Meter malfunction)	244	Omitted (Dredging in Progress)	Omitted (Not sampled)	276	54	160	206
Other Diatoms[2]	496	364		37	8	350	319		271			271	39	26	20
Anabaena[1]	10	0		17	18	0	16		3			5	19	7	9
Aphanizomenon[1]	0	0		0	10	0	0		9			0	37	37	67
Oscillatoria[2]	0	21		12	44	0	0		18			21	67	30	29
Other Blue Green[4]	21	37		57	20	5	21		22			21	12	24	19
Desmids[3]	0	0		2	1	5	0		1			5	14	2	12
Dinoflagellates[3]	0	0		0	0	0	0		0			0	0	0	0
Ulotrichales[1]	0	0		3	0	10	0		7			5	9	7	9
Other Green[3]	5	124		21	12	48	94		52			199	37	25	47

	Sta. 6					Sta. 7					Sta. 8c				
Melosira[1]	141	256	39	87	60	146	78	11	33	220	224	224	13	125	36
Other Diatoms[2]	282	245	17	4	12	239	192	6	3	29	418	282	3	11	19
Anabaena[1]	0	0	29	4	8	5	0	7	1	5	0	5	15	9	2
Aphanizomenon[1]	0	0	49	49	282	0	0	48	34	244	0	0	228	85	23
Oscillatoria[2]	63	172	45	38	25	115	240	56	46	151	146	94	83	62	48
Other Blue Green[4]	26	5	33	33	26	83	0	10	5	170	16	5	9	82	29
Desmids[3]	21	26	15	6	30	0	0	22	5	11	16	52	23	1	0
Dinoflagellates[3]	10	0	0	0	0	5	21	0	0	0	5	0	4	0	1
Ulotrichales[1]	0	16	2	5	4	10	42	2	3	30	0	37	13	23	10
Other Green[3]	255	401	32	39	58	256	192	34	2	121	-	829	24	36	15

1 No. X 10^3 filaments/liter
2 " frustules/liter
3 " cells/liter
4 " colonies/liter (predominantly Microcystis)

0 less than 1 X 10^3 or not observed

TABLE III-3 (continued)

	Sta. 9b					Sta. 12					Sta. 13				
	May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.
Melosira[1]	136	73	6	7	19	141	469	1	85	22	115	282	12	393	167
Other Diatoms[2]	328	432	2	1	19	230	573	3	8	2	240	302	13	54	6
Anabaena[1]	0	5	34	3	1	0	0	19	4	2	0	0	19	20	22
Aphanizomenon[1]	0	0	158	17	4	0	0	273	46	122	0	0	267	138	1047
Oscillatoria[2]	125	120	60	78	68	16	222	33	33	21	26	50	48	28	76
Other Blue Green[4]	0	10	4	3	6	16	183	13	46	91	10	10	26	38	313
Desmids[3]	0	62	5	7	1	10	65	0	1	2	16	21	2	22	22
Dinoflagellates[3]	5	5	1	0	0	0	39	0	0	0	0	0	0	0	0
Ulotrichales[1]	10	31	6	4	4	26	130	6	5	12	0	5	19	12	28
Other Green[3]	142	162	5	0	7	588	1461	12	2	24	129	395	60	68	16

	Sta. 14					Sta. 17					Sta. 24				
Melosira[1]	130	224	6	142	40	125	63	2	30	50	89	10	1	24	10
Other Diatoms[2]	209	150	1	21	3	449	208	4	0	23	464	167	5	2	13
Anabaena[1]	5	0	65	5	5	0	0	16	2	2	0	0	9	1	3
Aphanizomenon[1]	0	5	500	87	181	0	0	24	12	47	0	0	53	35	61
Oscillatoria[2]	31	63	18	36	42	162	334	135	93	27	198	203	47	94	45
Other Blue Green[4]	26	0	16	60	188	0	0	2	5	8	52	0	2	5	7
Desmids[3]	0	21	3	2	12	0	5	13	3	3	0	0	8	2	0
Dinoflagellates[3]	0	0	0	0	0	10	10	1	0	4	16	0	1	0	1
Ulotrichales[1]	0	26	6	22	10	26	83	2	2	4	21	10	3	7	4
Other Green[3]	260	499	11	120	16	114	99	4	4	9	255	31	0	1	5

1 No. X 10^3 filaments/liter
2 " frustules/liter
3 " cells/liter
4 " colonies/liter (predominantly Microcystis)

0 Less than 1 X 10^3 or not observed

TABLE III-3 (continued)

	Sta. 27					Sta. 31					Sta. 35				
	May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.
Melosira[1]	Omitted (Not sampled)	115	11	15	43	21	89	1	1	3	Omitted (No sample taken)	78	0	3	4
Other Diatoms[2]		281	4	1	51	323	188	3	3	34		468	2	9	6
Anabaena[1]		0	31	1	1	0	0	6	0	1		0	4	1	1
Aphanizomenon[1]		0	293	17	32	0	0	55	17	14		0	20	11	2
Oscillatoria[2]		334	104	61	140	172	245	72	58	260		443	16	117	78
Other Blue Green[4]		0	2	2	6	0	21	1	1	6		13	0	1	1
Desmids[3]		26	12	7	5	5	36	3	6	6		26	1	14	1
Dinoflagellates[3]		0	0	1	4	10	0	2	0	1		0	1	5	0
Ulotrichales[1]		0	12	3	2	5	0	5	1	3		0	6	0	3
Other Green[3]		245	9	2	8	65	136	9	1	3		268	5	1	1

	Sta. 43					Sta. 45				
	May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.
Melosira[1]	21	45	Omitted (Meter malfunction)	3	3	Omitted (No sample taken)	73	Omitted (Meter malfunction)	0	4
Other Diatoms[2]	294	333		12	11		296		2	32
Anabaena[1]	0	0		2	0		0		2	0
Aphanizomenon[1]	0	0		3	10		0		18	12
Oscillatoria[2]	37	323		80	88		402		65	143
Other Blue Green[4]	0	0		2	0		0		2	1
Desmids[3]	0	26		6	3		20		12	6
Dinoflagellates[3]	5	26		1	2		0		0	0
Ulotrichales[1]	10	42		5	3		10		3	2
Other Green[3]	56	104		10	6		123		1	1

1 No. X 10^3 filaments/liter
2 " frustules/liter
3 " cells/liter
4 " colonies/liter (predominantly Microcystis)

0 less than 1 X 10^3 or not observed

TABLE III-4

Active Chlorophyll-a and Biomass

		Chlorophyll-a ** ug/1					Plankton Biomass* mg/1	
	Station	May	June	July	Aug.	Sept.	May	June
Inner Bay Zone	1	13.3	17.1	27.0	75.2	55.0	5.9	4.5
	2	10.1	17.6	26.0	53.5	47.6	2.4	3.3
	4	--	21.7	26.6	5.0	5.2	-	4.1
	6	12.5	8.4	26.0	0	6.7	2.4	3.7
	12	14.6	22.8	25.9	10.1	34.2	1.9	4.8
	13	9.5	18.2	35.3	1.6	61.8	1.5	3.1
	14	13.0	13.4	57.6	9.2	20.1	2.9	3.4
	Aver.	12.2	17.0	32.1	22.1	32.9	2.8	3.8
Eastern Zone	7	12.3	9.4	17.3	0.8	0	3.8	2.8
	8c	31.1	18.0	24.2	13.3	2.5	3.7	3.2
	9b	12.6	9.4	11.3	0	3.3	4.0	2.3
	27	--	9.6	17.6	0.8	15.1	-	3.4
	Aver.	18.7	11.6	17.6	3.7	5.2	3.8	2.9
West Central Zone	17	1.3	9.3	10.4	0.8	10.1	2.5	3.2
	24	9.9	5.7	6.7	0	16.7	2.5	2.0
	31	4.5	5.4	4.3	4.2	10.8	1.0	3.7
	35	--	6.2	3.6	9.1	5.9	-	3.1
	43	3.8	6.6	11.7	4.1	--	1.3	2.9
	45	--	9.4	5.3	0	3.3	-	2.6
	Aver.	4.9	7.1	7.0	3.0	9.4	1.8	2.9

* Plankton biomass based on total volatile solids minus organic debris.
** Chlorophyll-a minus phaeo-pigments

SECTION IV

IV. WATER QUALITY MODELLING

Introduction: Water quality computer models were developed whose purpose was to establish the capacity of Green Bay to respond to the input of various pollutants and other chemicals. The first model to be discussed consists of a version of the QUAL-II Model developed by Norton et al WRE, Inc. (1974) under EPA contract no. 68-01-0713-Upper Mississippi River Basin Model Project. The Wisconsin DNR has modified and implemented this model for the Lower Fox River system.

A second model was based on a program by Water Resources Engineers, Inc., Lee et al (1974) to simulate two dimensional systems such as Green Bay. This Dynamic Estuary Model was modified to fit the Green Bay system and to simulate the major water quality constituents. This model and its modifications are discussed in detail in Appendix D (Green Bay Model Development and Documentation).

The Qual II model (as modified and used by DNR) is capable of simulating 12 constituents under steady or psuedo-dynamic conditions. BOD and DO are routed as well as phosphorus, 4 forms of nitrogen, algae, coliforms and up to three conservative substances. The model uses one dimensional steady state hydraulics and waste inputs for both steady and dynamic runs. Dynamic simulation allows the insertion of variable light intensity for evaluating the diurnal effect of algae photosynthesis and respiration.

NOTE: In 1973 the Wisconsin DNR published a Water Quality Model Study of the Lower Fox River, Patterson (1973). This study was based on a water quality model developed by Crevensten, Stoddard and Vajda of EPA. Since that time this model has been used to produce a Waste Load Allocation for the Oconto River (Wisconsin DNR, 1974). Since the waste load allocation for the Oconto River has been completed, no additional simulations for the Oconto River have been undertaken. The results of the Oconto River modeling are not presented in this report.

A. Fox River Modelling

The Fox River from Lake Winnebago to Green Bay, a distance of about 40 miles, was simulated by means of the QUAL-II computer model. The advantage of the QUAL-II model is its flexibility and capability of simulating simultaneously many constituents. For instance, four forms of nitrogen can be routed while various chemical or biological reactions take place.

The QUAL-II model has been extensively modified in its application to the Lower Fox River. The four most important modifications include: 1) the ability to simulate organic nitrogen, 2) reformulization of the algal growth kinetics, 3) inhibiting nitrification rates at low dissolved oxygen levels and 4) allowing for denitrification during very low dissolved oxygen levels. The first two modifications are essentially similar to the scheme developed for the Bay model (Appendix D). The appropriate theory and equations are discussed in the Green Bay model documentation. The third and fourth modifications are consistent with observations reported in past literature and commonly accepted theory. With the exception of the above changes, the model operates as described by the WRE program documentation, Norton et al (1974).

FIGURE IV-1a
Lower Fox River Modelling Segments

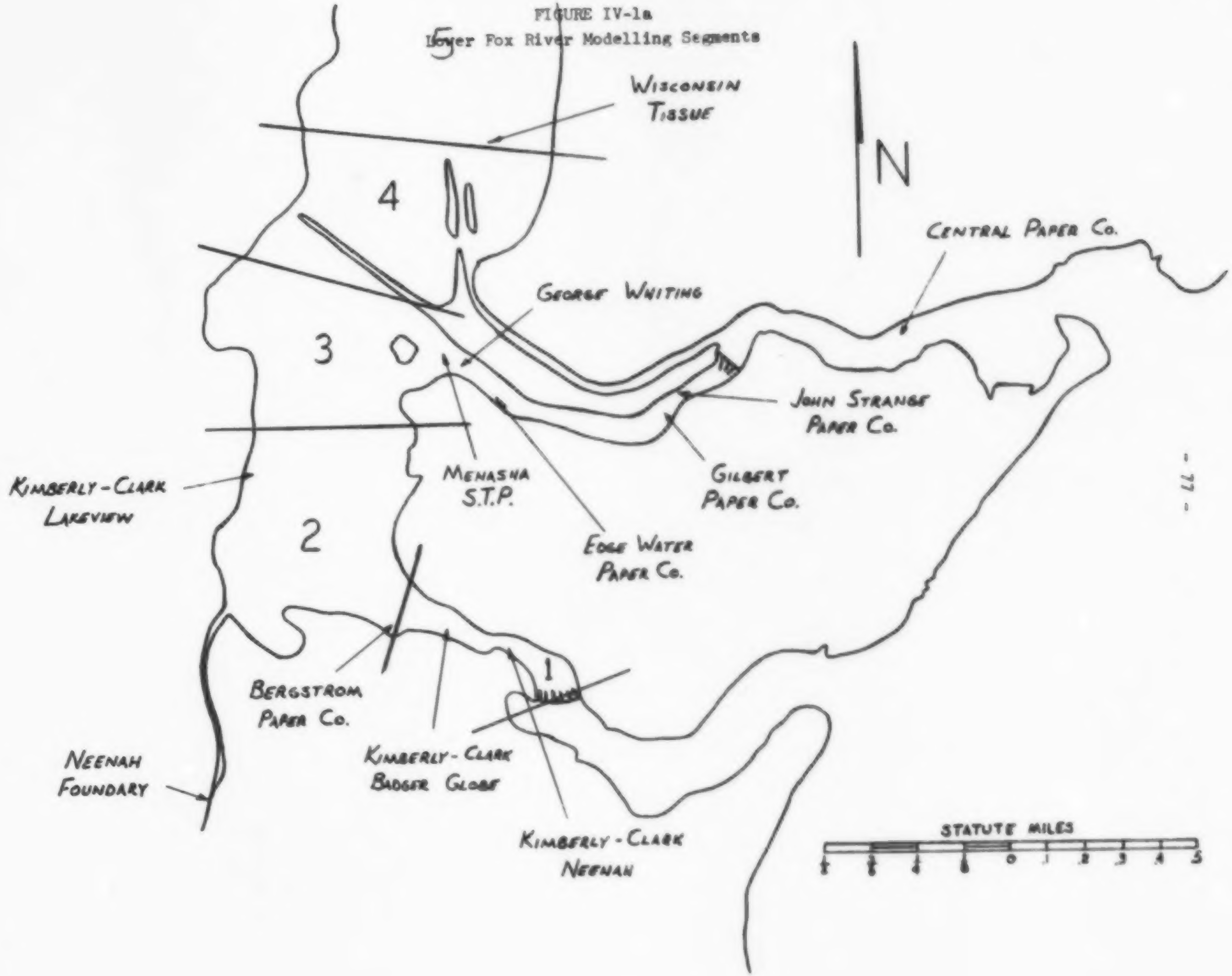

5
Wisconsin Tissue
N
4
Central Paper Co.
George Whiting
3
John Strange Paper Co.
Kimberly-Clark Lakeview
Menasha S.T.P.
Gilbert Paper Co.
2
Edge Water Paper Co.
1
Bergstrom Paper Co.
Neenah Foundary
Kimberly-Clark Badger Globe
Kimberly-Clark Neenah
STATUTE MILES
1
0
.1
.2
.3
.4
.5

FIGURE IV-1b

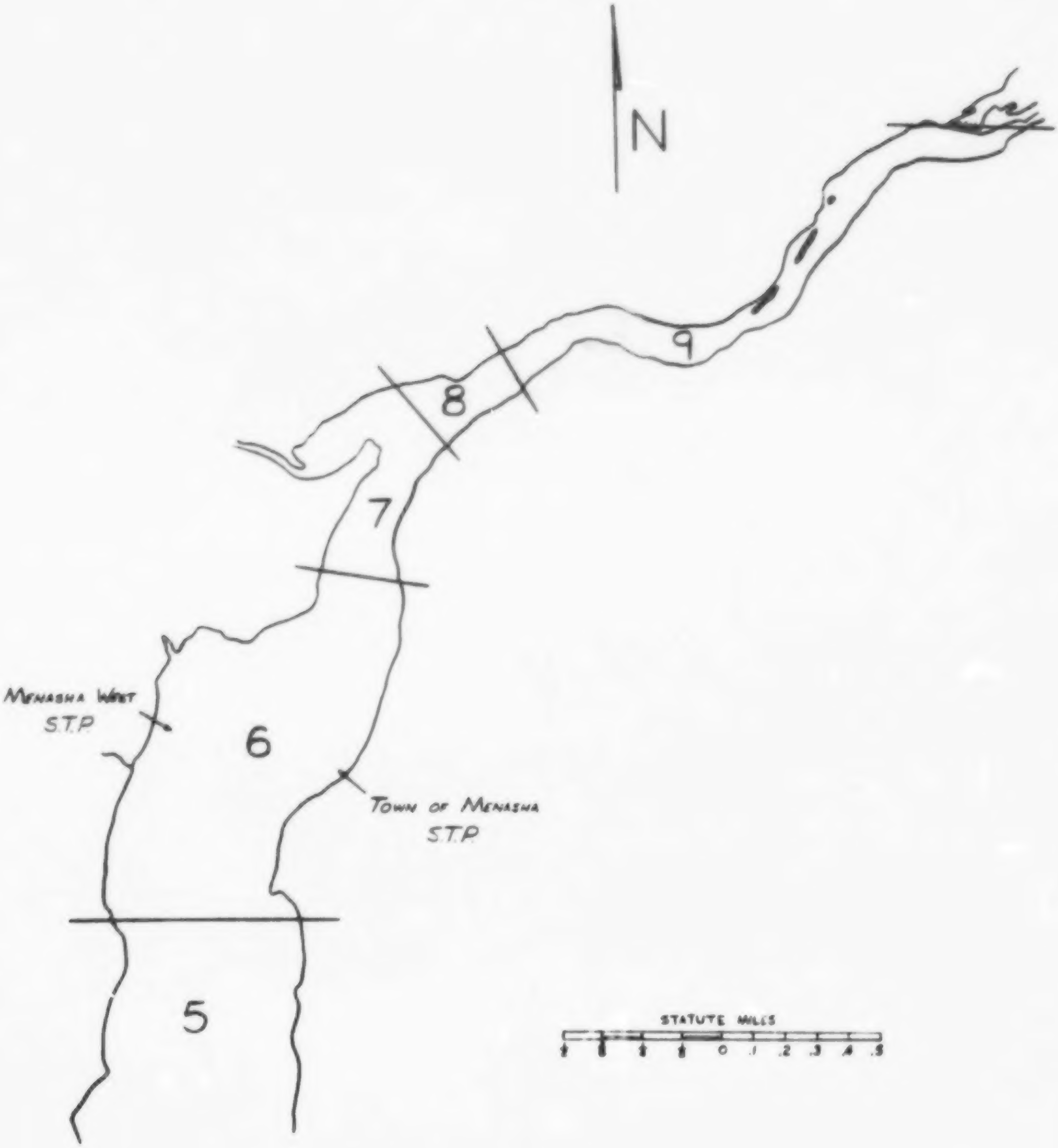

N
9
8
7
6
5
Menasha West
S.T.P.
Town of Menasha
S.T.P.
STATUTE MILES
0
.1
.2
.3
.4
.5

FIGURE IV-1c

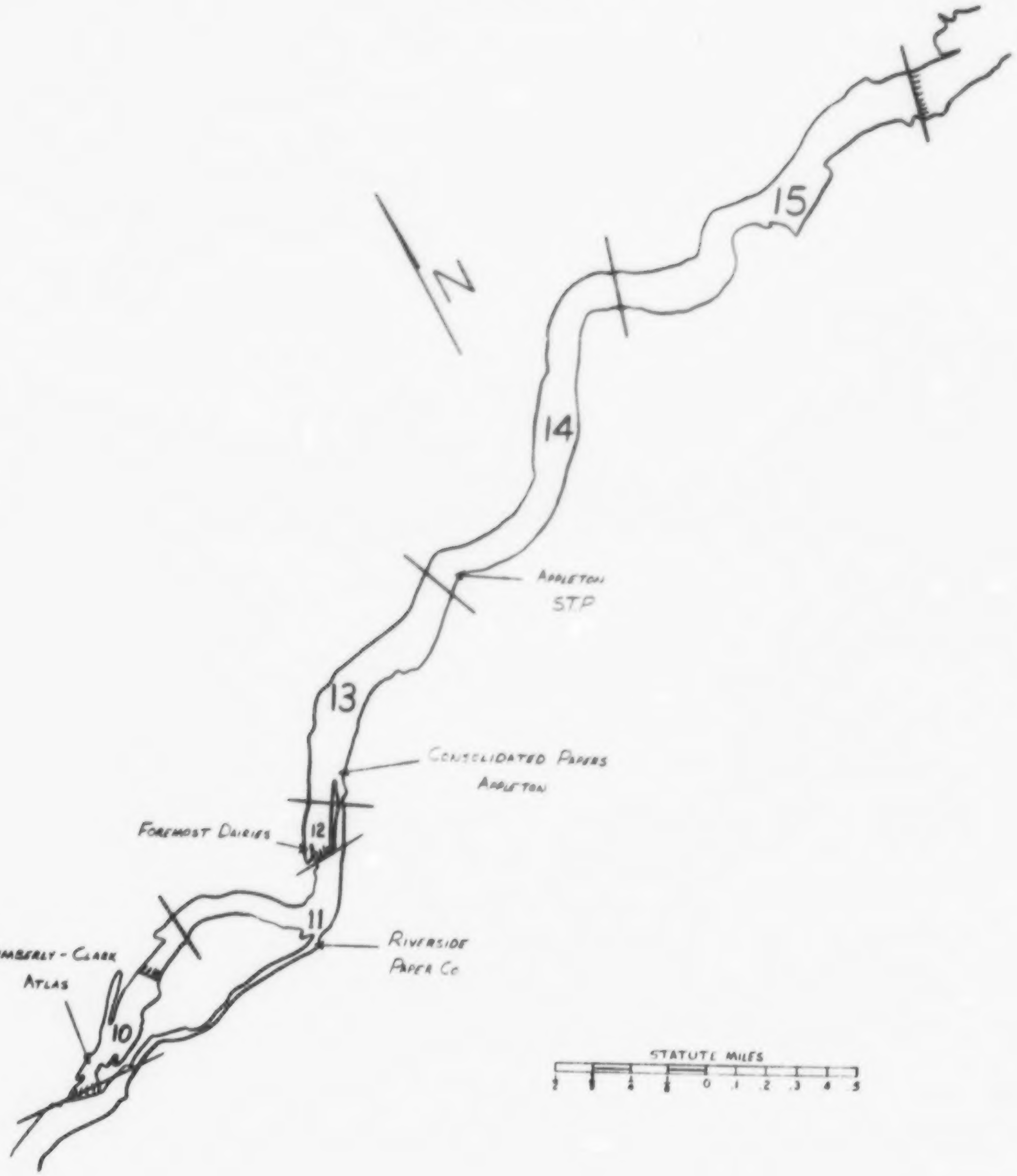

N
15
14
Appleton
S.T.P
13
Consolidated Papers
Appleton
Foremost Dairies
12
11
Riverside
Paper Co
Kimberly-Clark
Atlas
10
STATUTE MILES
0
.1
.2
.3
.4
.5

FIGURE IV-1d

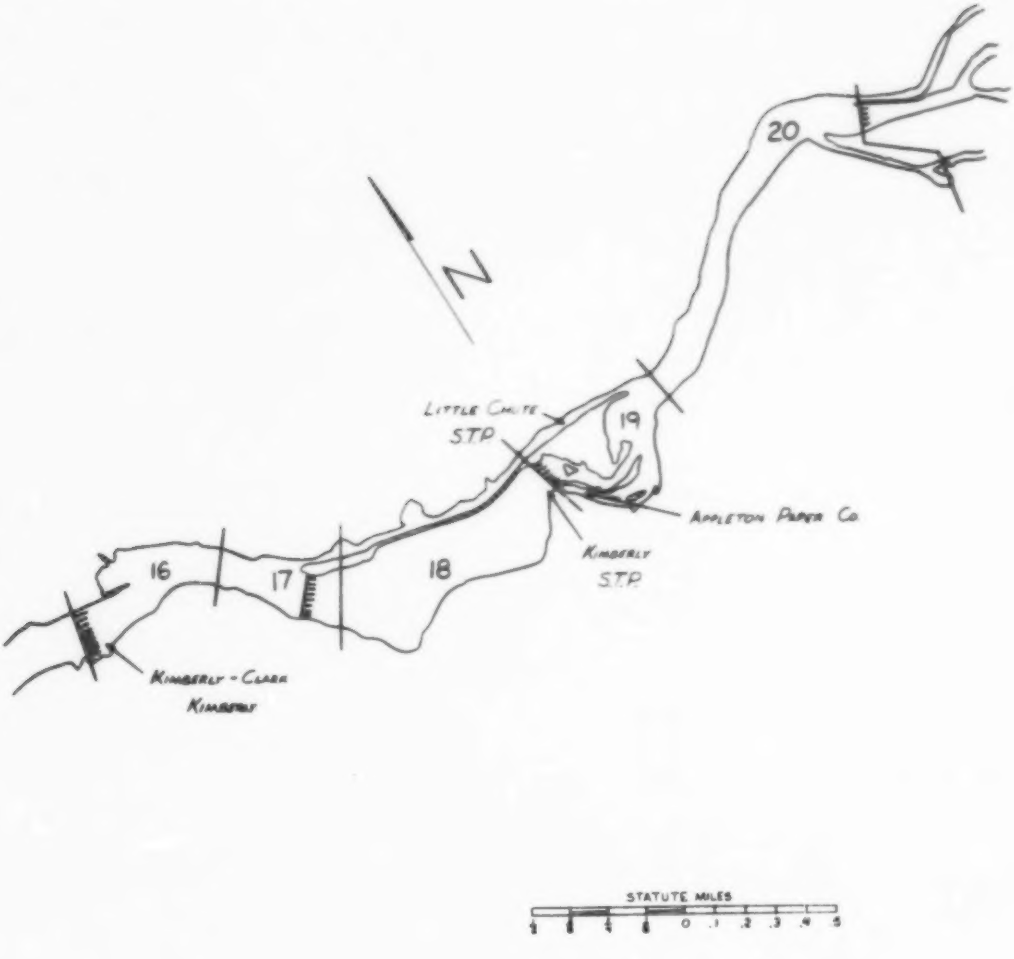

N
20
19
Little Chute S.T.P.
Appleton Paper Co.
Kimberly S.T.P.
16
17
18
Kimberly - Clark Kimberly
STATUTE MILES
0
.1
.2
.3
.4
.5

FIGURE IV-1e

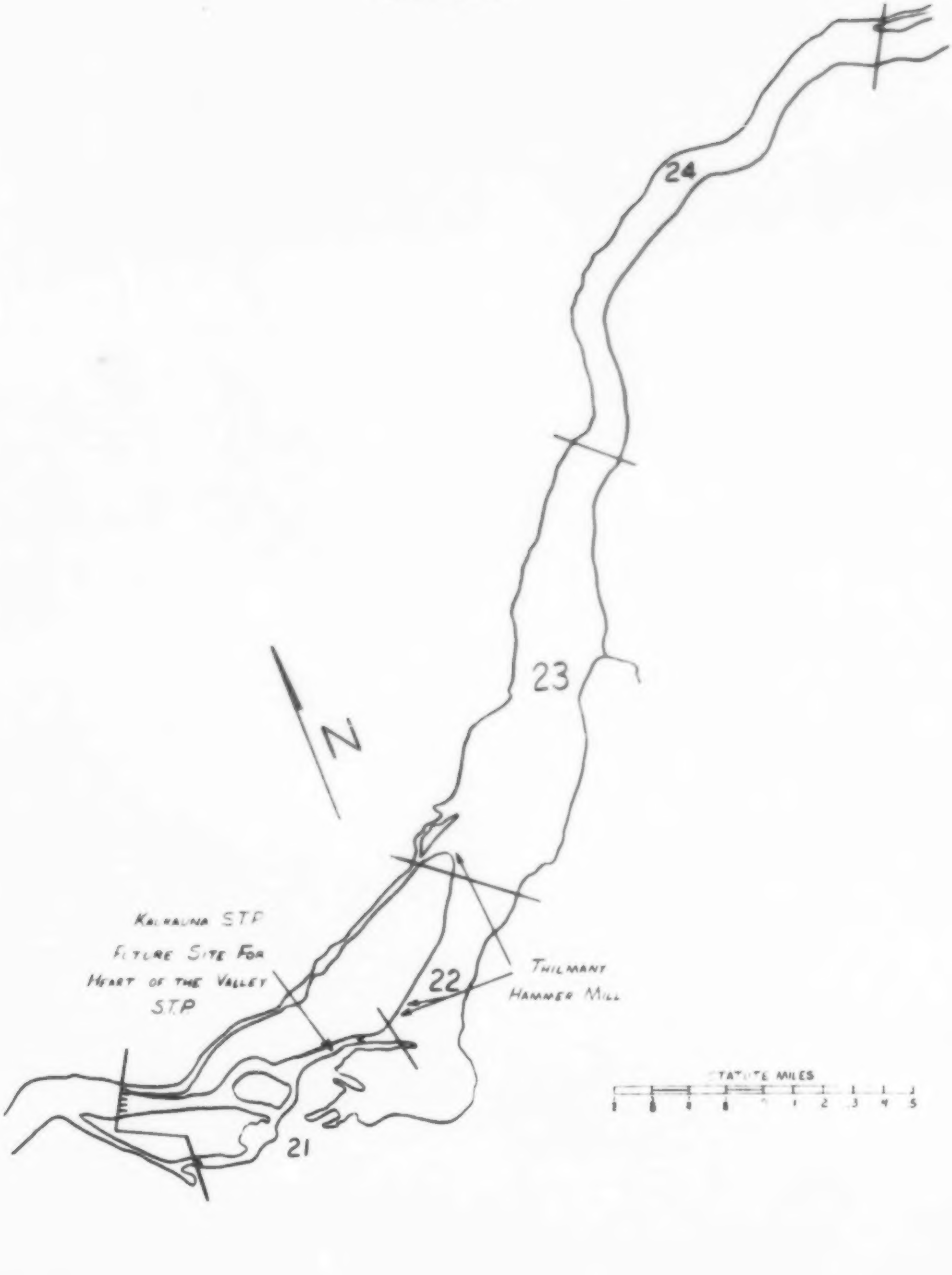

24
23
22
21
N
KAUKAUNA STP
FUTURE SITE FOR
HEART OF THE VALLEY
STP
THILMANT
HAMMER MILL
STATUTE MILES
1 2 3 4 5

FIGURE IV-1f

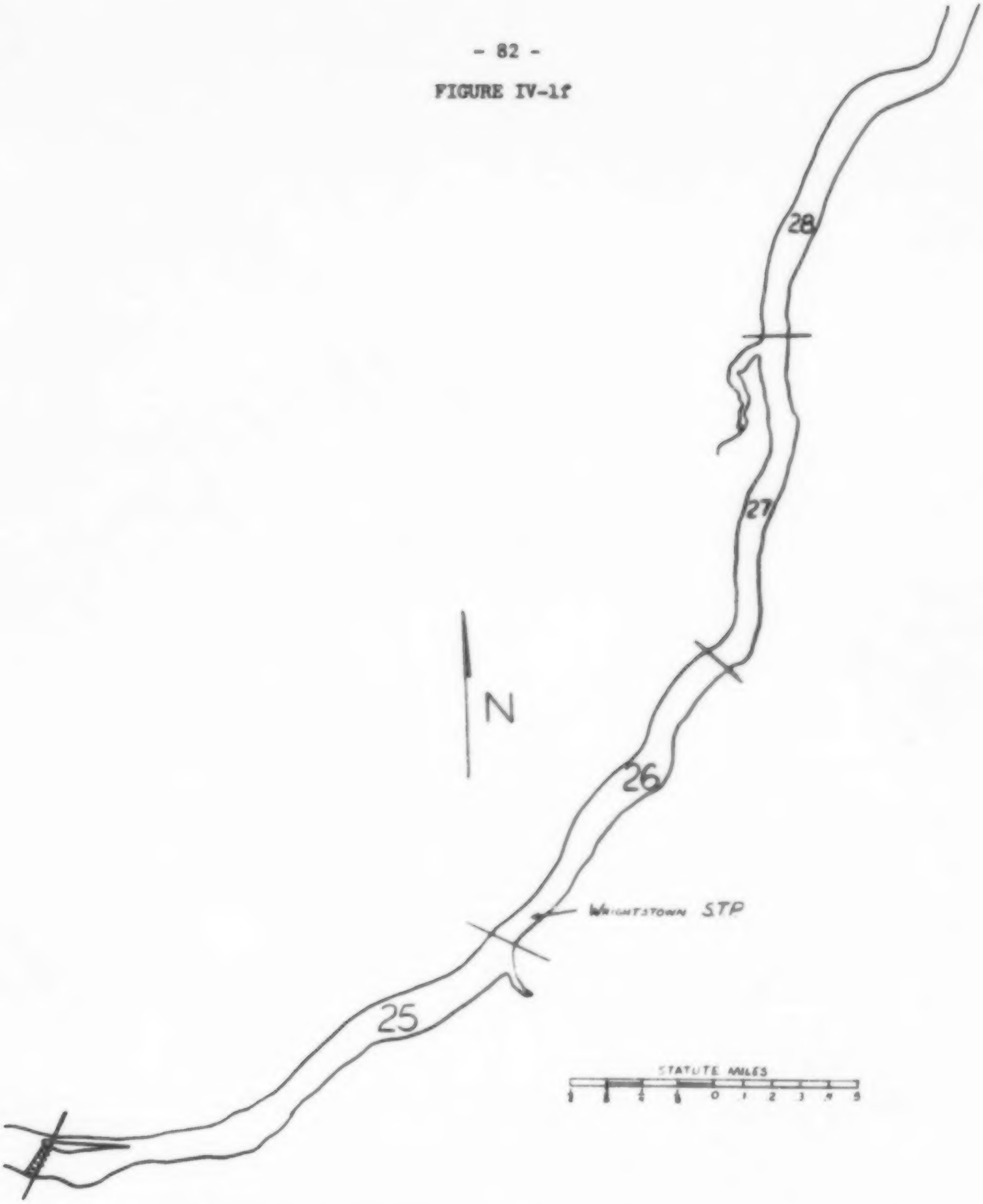

28
27
N
26
WRIGHTSTOWN STP
25
STATUTE MILES
0 1 2 3 4 5

FIGURE IV-1g

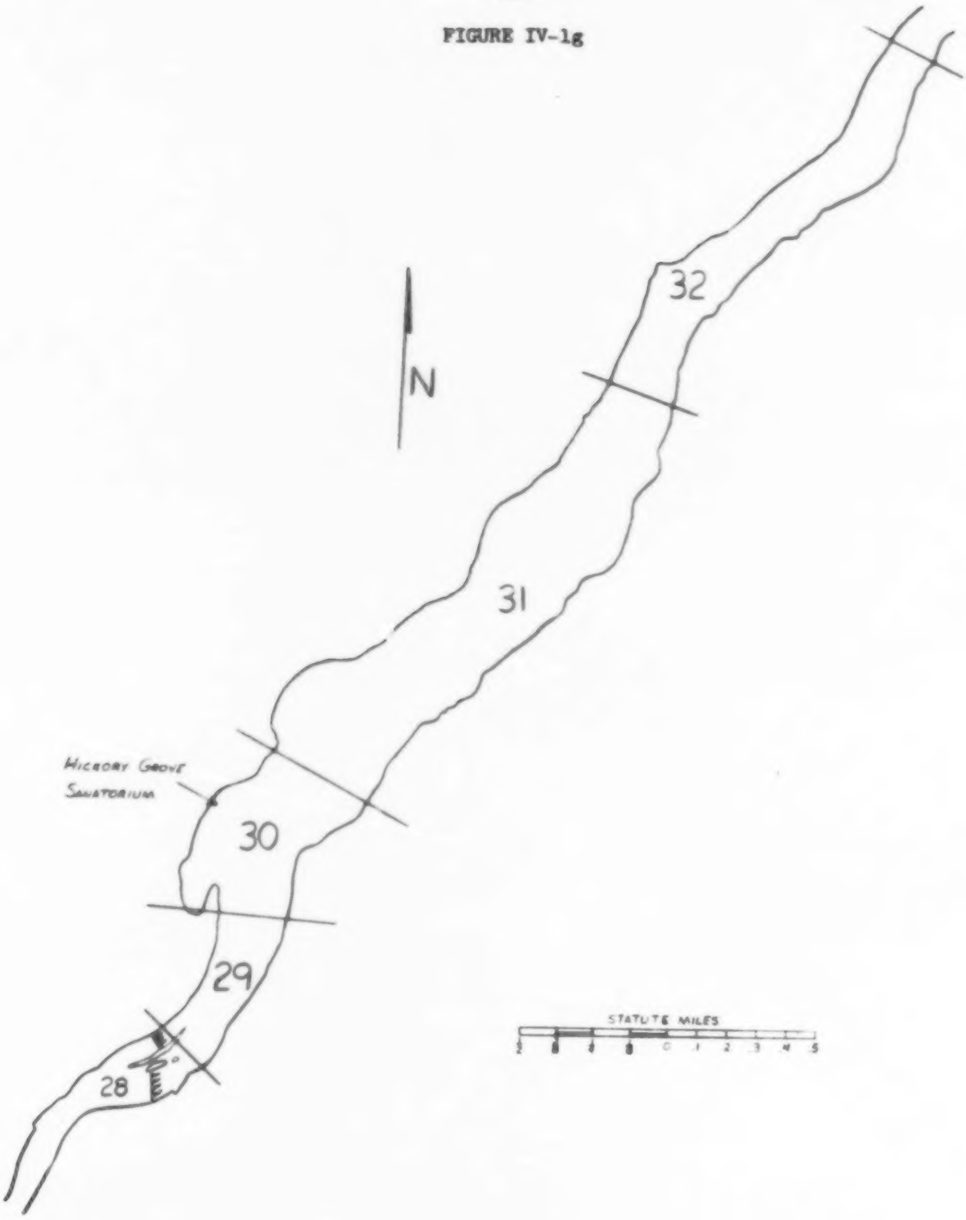

32
N
31
Hickory Grove Sanatorium
30
29
28
STATUTE MILES
0
1
2
3
4
5

FIGURE IV-1h

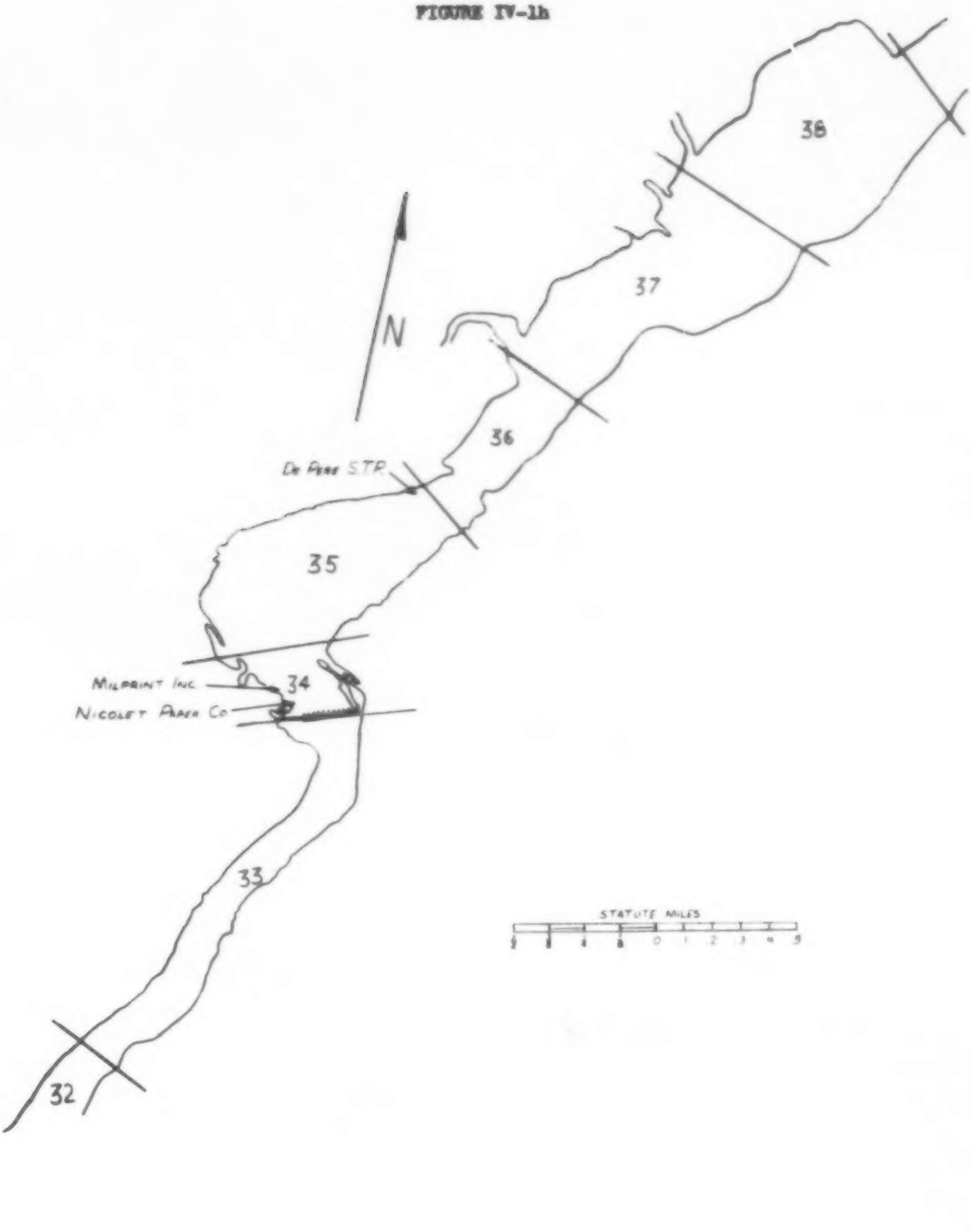
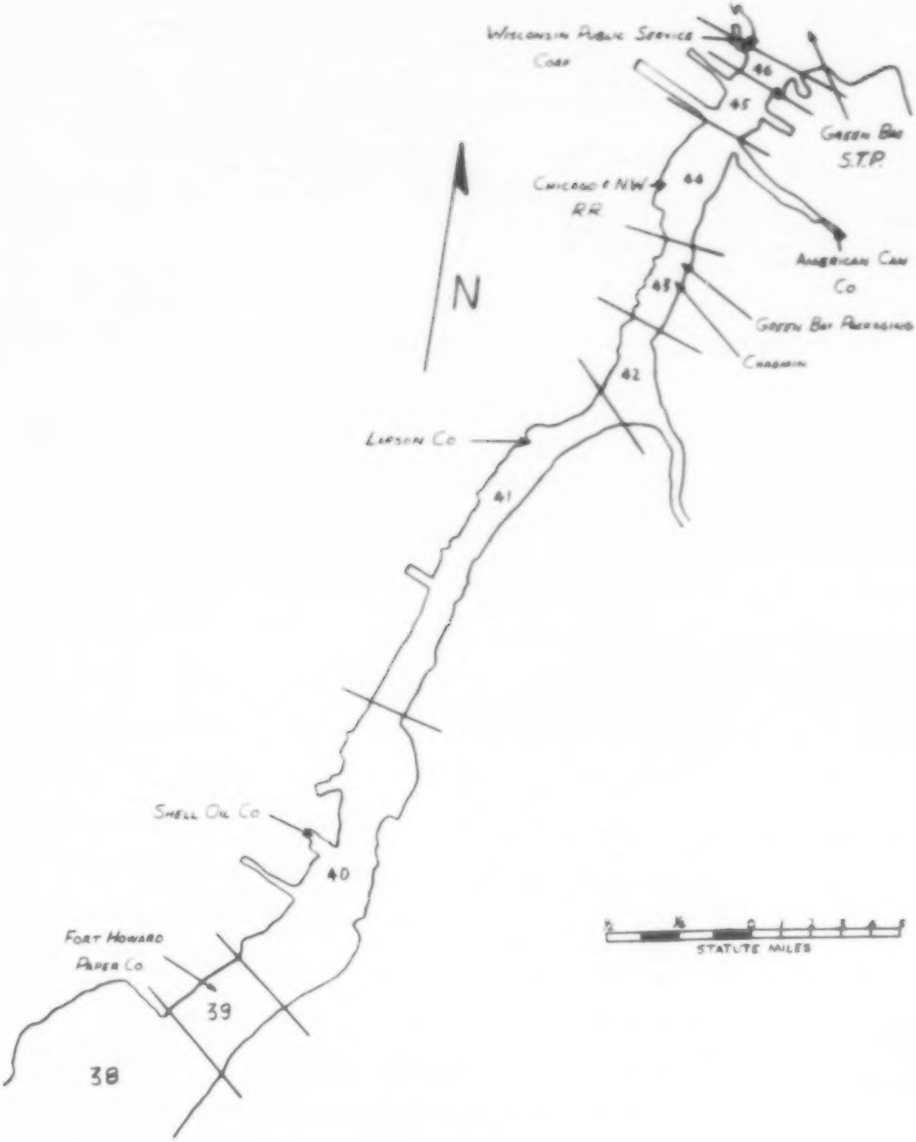

N
38
37
36
De Pere S.T.P.
35
34
Milprint Inc.
Nicolet Paper Co.
33
32
STATUTE MILES
0
1
2
3
4
5

FIGURE IV-11


Wisconsin Public Service Corp
46
45
Green Bay S.T.P.
Chicago & NW R.R.
44
American Can Co
43
Green Bay Packaging
Charmin
N
42
Larson Co
41
Shell Oil Co
40
Fort Howard Paper Co.
39
38
½ 0 1 2 3 4 5
STATUTE MILES

The QUAL-II model was then applied to the Lower Fox River. Forty-six river segments were used to describe the Fox River. Each segment was further divided into an integral number (from 1 to 20) of computational elements (each of these was 0.1 miles in length). In all, 389 computational elements were used. The waste sources were located along the system and were used as waste inputs at the appropriate computational element. The physical schematization is shown in Figure IV-1 and tabulated in Table IV-1.

QUAL-II was verified using data obtained in the summer of 1972. This is the same data used to verify the EPA model. The results of the verification run for June 20-21, 1972 are presented in Figures IV-2 through IV-5. Survey data was obtained during daylight hours only. Data from the 5 automatic monitors is presented to indicate the duirnal range of the DO during the survey period. The profiles for DO, BOD_5, NH_3-N, NO_3-N, Org-N, and Chlorophyll-a are presented along with the data that is available. The verification run shows an agreement between the observed data and the QUAL-II prediction that is very acceptable. It is particularly interesting to observe the agreement for the nitrogen forms. The only area of significant disagreement is in the NO_3-N profile for run one between mile points 14 and 0. The QUAL-II model indicates a 100% increase in the NO_3-N concentration while the data indicates no substantial change in the NO_3-N level. Since the other forms of nitrogen show good agreement with the data, one of two possible things is taking place to account for this discrepancy. Either the DO levels are low enough near the sediments to stimulate a significant amount of denitrification at the lower end, or nitrification is not taking place at the rate used in the model for run one. The first hypothesis is in direct disagreement with the observed DO profile. Mile 14.0 to 3.0 shows DO levels much too high to allow for significant denitrification (Figure IV-2) unless there is a very strong vertical stratification which would allow the DO level to drop sharply near the water sediment interface. Thus the first hypothesis is not very likely.

FIGURE IV-2

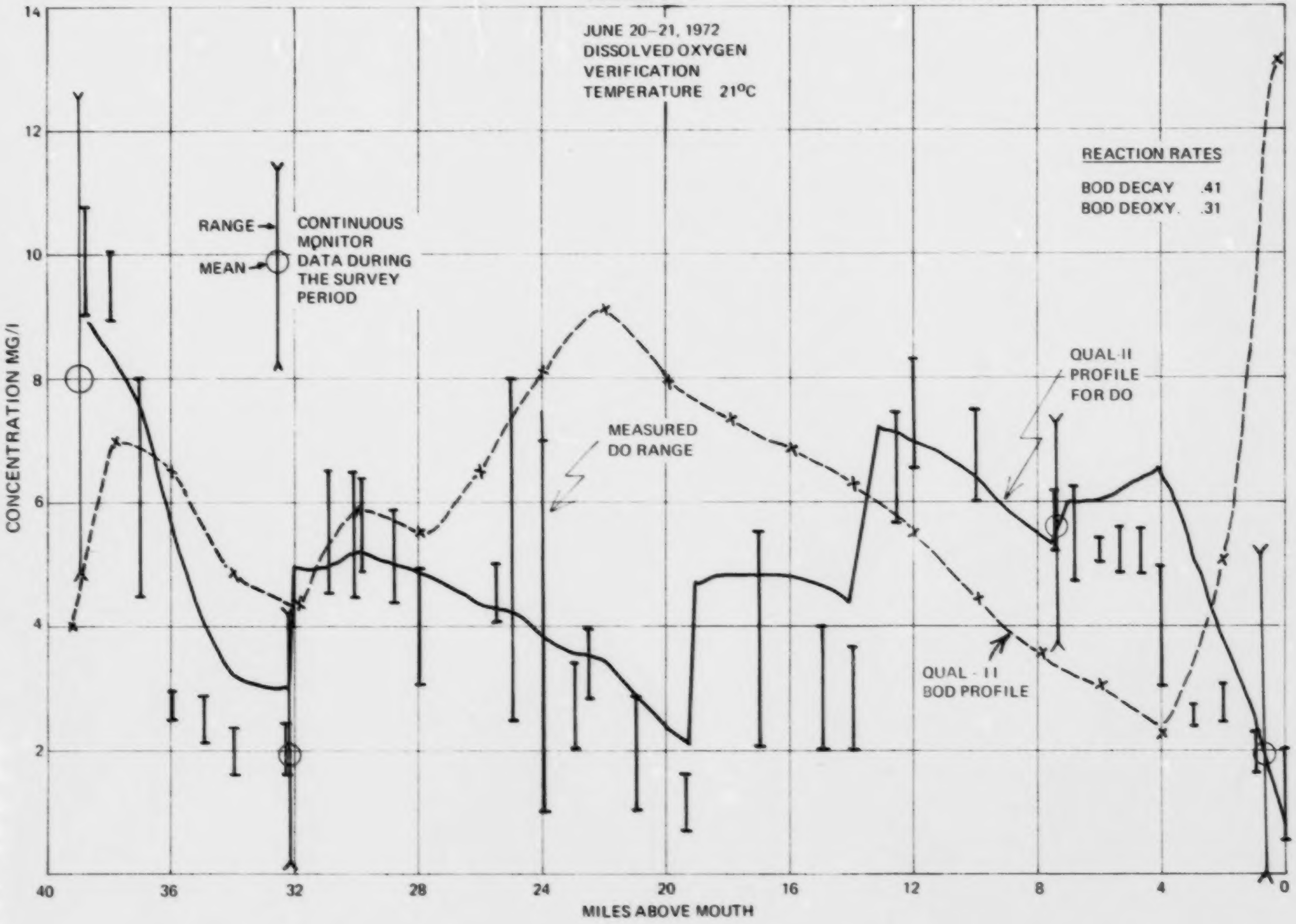
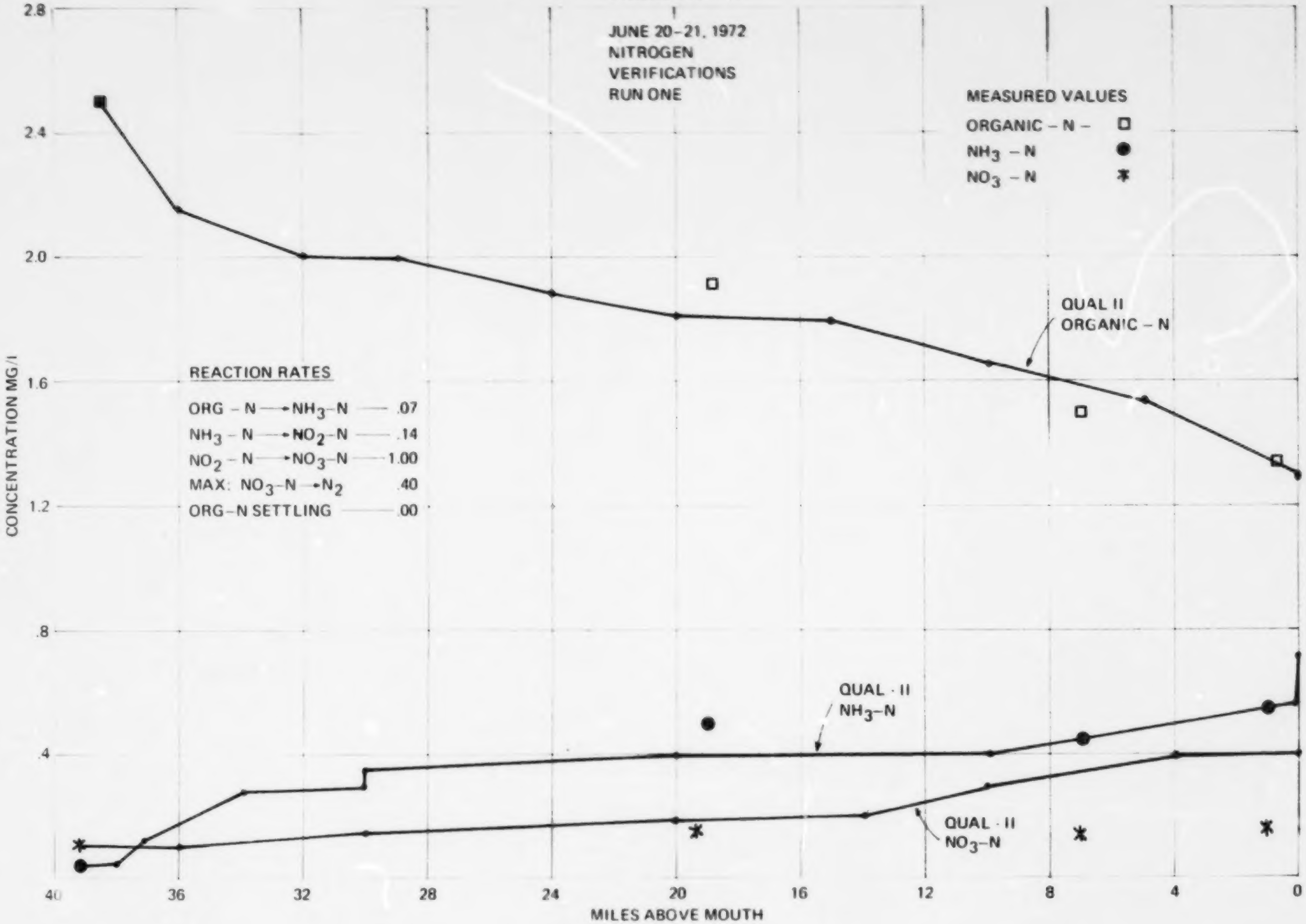

JUNE 20–21, 1972
DISSOLVED OXYGEN
VERIFICATION
TEMPERATURE 21°C
REACTION RATES
BOD DECAY .41
BOD DEOXY. .31
RANGE
MEAN
CONTINUOUS MONITOR DATA DURING THE SURVEY PERIOD
MEASURED DO RANGE
QUAL-II PROFILE FOR DO
QUAL - II BOD PROFILE
CONCENTRATION MG/l
MILES ABOVE MOUTH
14
12
10
8
6
4
2
40
36
32
28
24
20
16
12
8
4
0

FIGURE IV – 3



JUNE 20–21, 1972
NITROGEN
VERIFICATIONS
RUN ONE

FIGURE IV – 4

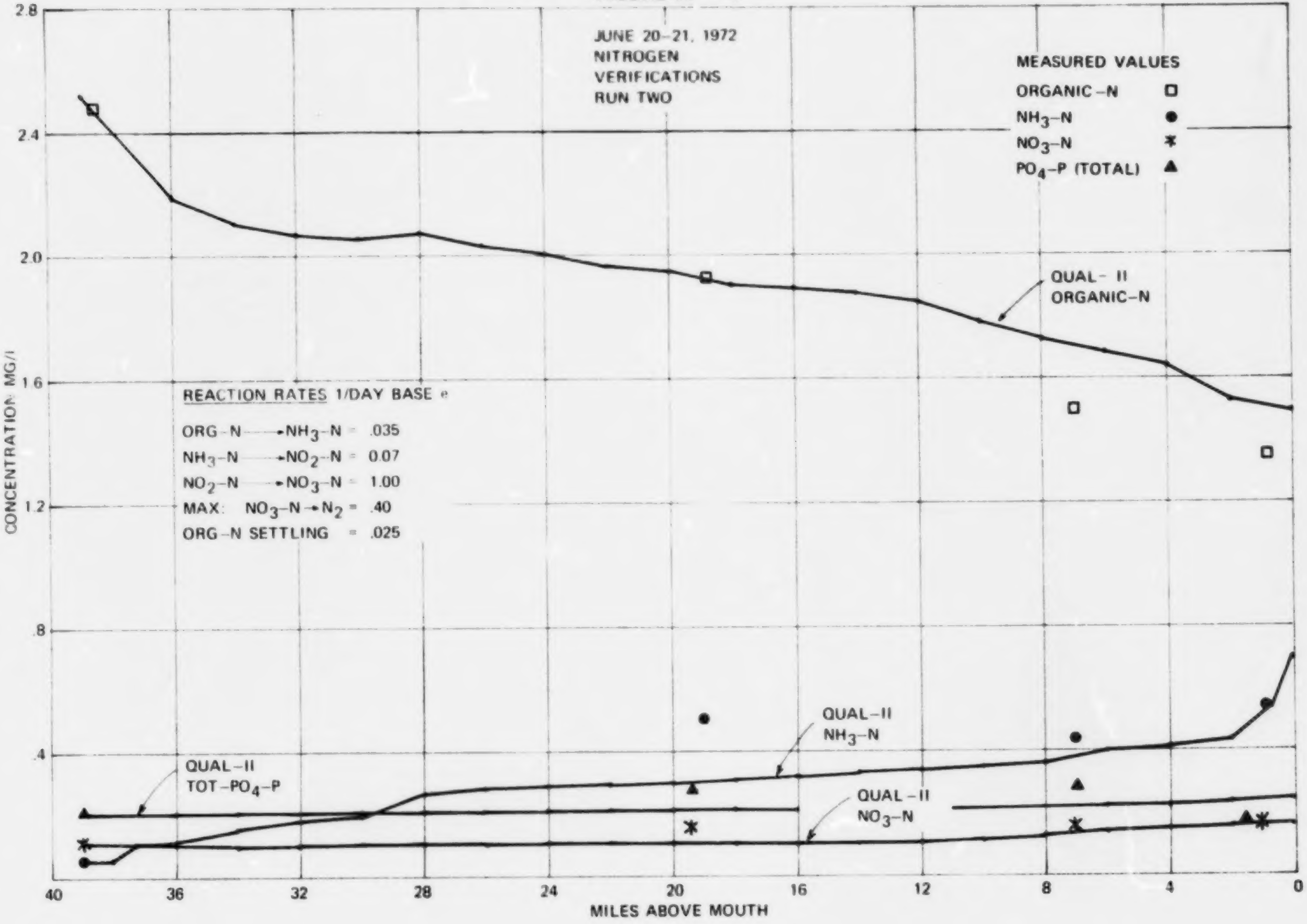
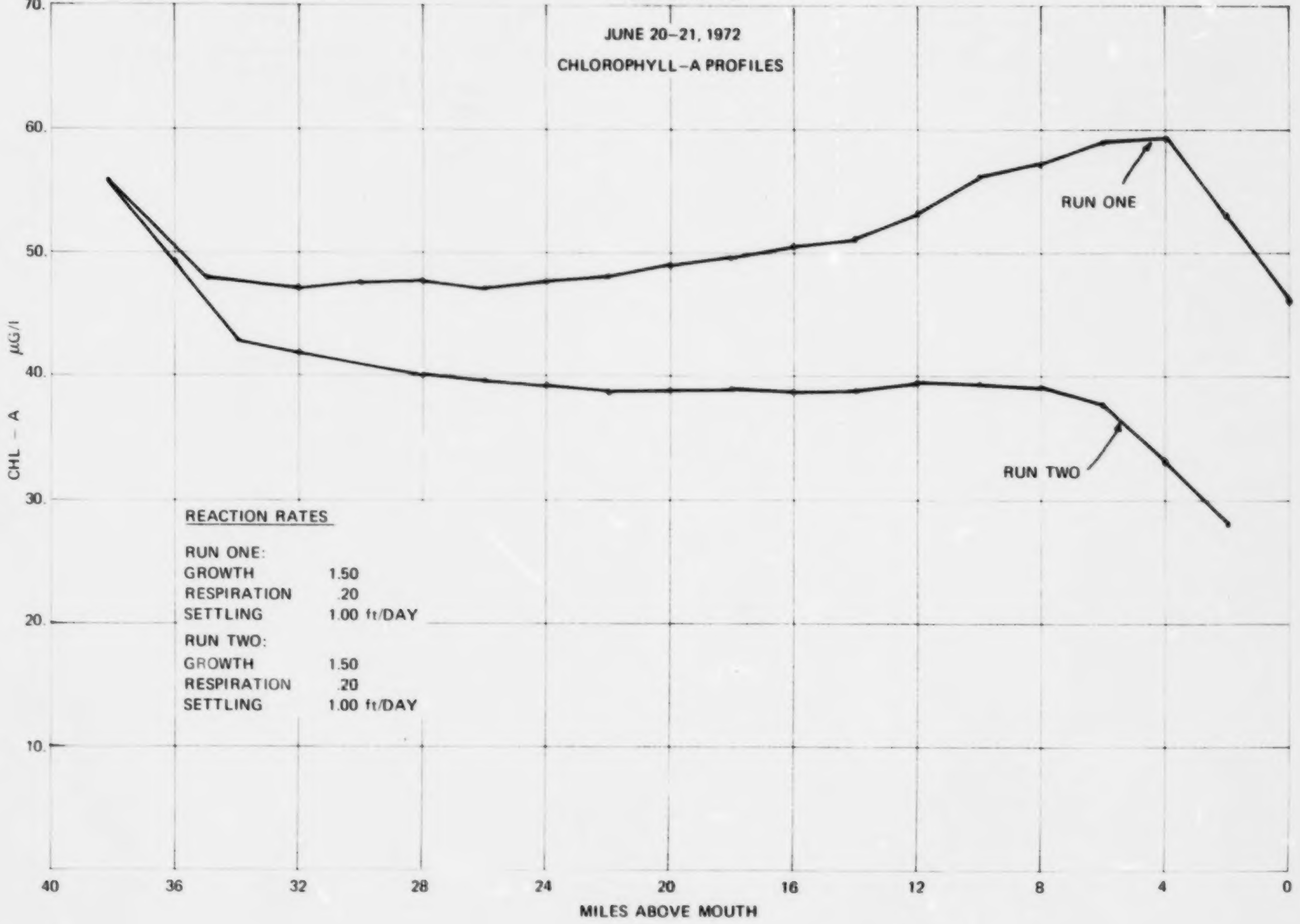

JUNE 20–21, 1972
NITROGEN
VERIFICATIONS
RUN TWO
MEASURED VALUES
ORGANIC–N □
NH_3–N ●
NO_3–N ✱
PO_4–P (TOTAL) ▲
QUAL– II
ORGANIC–N
REACTION RATES 1/DAY BASE e
ORG–N ⟶ NH_3–N = .035
NH_3–N ⟶ NO_2–N = 0.07
NO_2–N ⟶ NO_3–N = 1.00
MAX: NO_3–N ⟶ N_2 = .40
ORG–N SETTLING = .025
QUAL–II
NH_3–N
QUAL–II
TOT–PO_4–P
QUAL–II
NO_3–N
CONCENTRATION MG/l
2.8
2.4
2.0
1.6
1.2
.8
.4
40
36
32
28
24
20
16
12
8
4
0
MILES ABOVE MOUTH

FIGURE IV – 5



JUNE 20–21, 1972

CHLOROPHYLL–A PROFILES

TABLE IV-1

Physical Dimensions Used to Describe the Lower Fox River

Reach Number	Cross Sectional Area Ft^2	Depth Ft.	Benthic Demand GR O_2/m^2/Day	
			Verification Runs	BPT Conditions
1.	967.	2.	8.0	3.0
2.	4020.	2.5	8.0	3.0
3.	6978.	3.	8.0	3.0
4.	11660.	4.	8.0	3.0
5.	14634.	4.5	8.0	3.0
6.	15065.	5.5	8.0	3.0
7.	9837.	9.	8.0	3.0
8.	10032.	9.6	8.0	3.0
9.	3670.	6.6	8.0	3.0
10.	1676.	4.	8.0	2.0
11.	1998.	4.5	8.0	2.0
12.	619.	1.6	5.0	2.0
13.	3648.	5.8	5.0	2.0
14.	4194.	6.7	5.0	2.0
15.	4194.	6.7	5.0	2.0
16.	2660.	3.3	5.0	2.0
17.	4556.	6.7	8.0	2.0
18.	6592.	6.5	8.0	2.0
19.	1492.	2.8	8.0	4.9
20.	3484.	6.3	8.0	4.9
21.	2900.	10.0	8.0	4.9
22.	1476.	2.	8.0	4.8
23.	6514.	4.7	8.0	4.8
24.	4703.	7.5	8.0	4.8
25.	2420.	4.	5.0	3.0
26.	2912.	5.8	5.0	3.0
27.	2912.	5.8	5.0	3.0
28.	4428.	7.7	5.0	3.0
29.	5055.	5.5	2.5	2.5
30.	8145.	5.0	2.5	2.5
31.	10146.	5.7	2.5	2.5
32.	9301.	10.3	2.5	2.5
33.	9301.	10.3	2.5	2.5
34.	4889.	3.4	2.5	3.0
35.	10824.	6.6	2.5	3.0
36.	8584.	7.4	2.5	3.0
37.	11665.	5.6	2.5	3.0
38.	15204.	5.6	2.5	3.0
39.	12042.	9.	2.5	3.0
40.	15002.	13.	5.0	3.0
41.	12978.	21.	5.0	3.0
42.	16055.	19.	5.0	3.0
43.	11380.	20.	5.0	3.0
44.	9945.	13.	5.0	3.0
45.	14025.	16.5	5.0	3.0
46.	12194.	13.	5.0	3.0

We are therefore left with the conclusion that nitrification rates for NH_3-N are being overestimated. If this is the case, we must account for the fact that the rate used in the model did in fact predict an ammonia profile that agrees nicely with the data. A closer look at the nitrogen balance discloses that organic nitrogen decreased a total of 1.1 mg/l while ammonia increased .43 mg/l and nitrate increased .11 mg/l. (Nitrite concentrations are normally insignificant i.e., <.05 mg/l.) Since the nitrogen forms do not balance we must conclude that nitrogen is leaving the system in a manner that is unaccounted for. One could immediately assume that algal growth could make up this difference. A closer check tells us that to account for the difference of .55 mg/l of nitrogen, we would need 6.9 mg/l of algal biomass (assuming an algae cell is about 8% nitrogen). Using literature conversion factors, (QUAL-II documentation), 6.9 mg/l of algal biomass would contain 350 to 690 ug/l of chlorophyll-a, an extremely high number.

This is in direct conflict with Sager & Wiersma's measurements of chlorophyll-a. His measurements indicate maximums of about 150 ug/l in the Menasha area and typically a 50% decrease from that level as one travels downstream to Green Bay (Figure IV-6). Secondly, nitrogen contained in the algae would be measured as organic nitrogen (if the sample was not filtered). We are therefore forced to assume that organic nitrogen must be leaving the system by sedimentation and not only by transformation to NH_3-N. Using this assumption, a second verification run is displayed in Figure IV-4. The drawn curves indicate a good fit for all the nitrogen forms. For run two, the observed and calculated total phosphorous curve is also shown and again the agreement is acceptable. Verification runs for July 5-6, 1972 and August 14, 1972 were also calculated. Dissolved oxygen data is again for daytime periods except for automatic monitoring data. The fits for these dates are not as good as the June 20-21, 1972 run. Data for comparison is not as complete for these simulations. These runs are diagrammed in Figures IV-7 through IV-11.

FIGURE IV-6

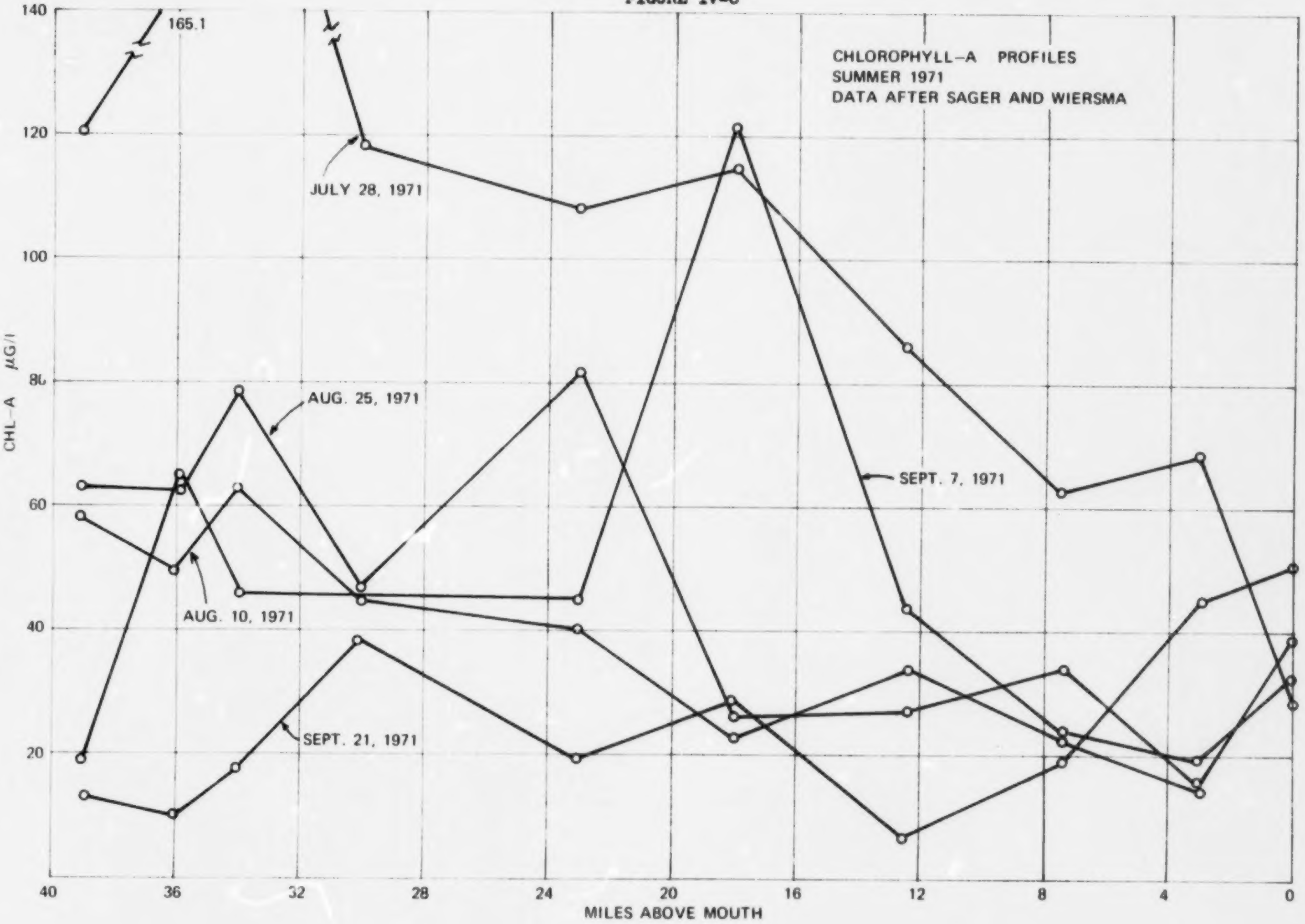

CHLOROPHYLL–A PROFILES
SUMMER 1971
DATA AFTER SAGER AND WIERSMA
165.1
JULY 28, 1971
AUG. 25, 1971
AUG. 10, 1971
SEPT. 7, 1971
SEPT. 21, 1971
CHL–A μG/l
140
120
100
80
60
40
20
40
36
32
28
24
20
16
12
8
4
0
MILES ABOVE MOUTH

FIGURE IV-7

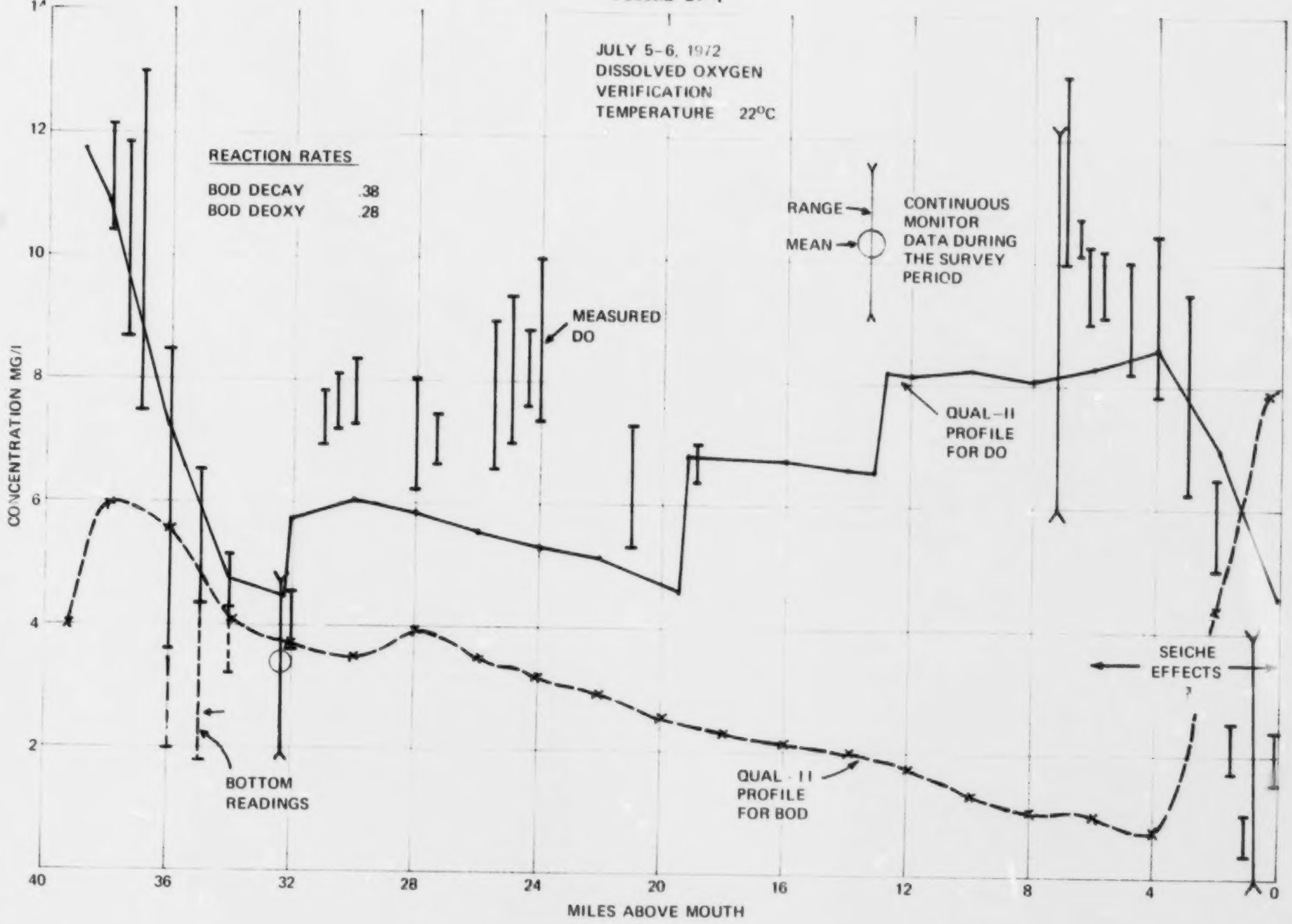

JULY 5-6, 1972
DISSOLVED OXYGEN
VERIFICATION
TEMPERATURE 22°C
REACTION RATES
BOD DECAY .38
BOD DEOXY .28
RANGE
MEAN
CONTINUOUS MONITOR DATA DURING THE SURVEY PERIOD
MEASURED DO
QUAL-II PROFILE FOR DO
QUAL-II PROFILE FOR BOD
BOTTOM READINGS
SEICHE EFFECTS ?
CONCENTRATION MG/l
14
12
10
8
6
4
2
40
36
32
28
24
20
16
12
8
4
0
MILES ABOVE MOUTH

FIGURE IV – 8

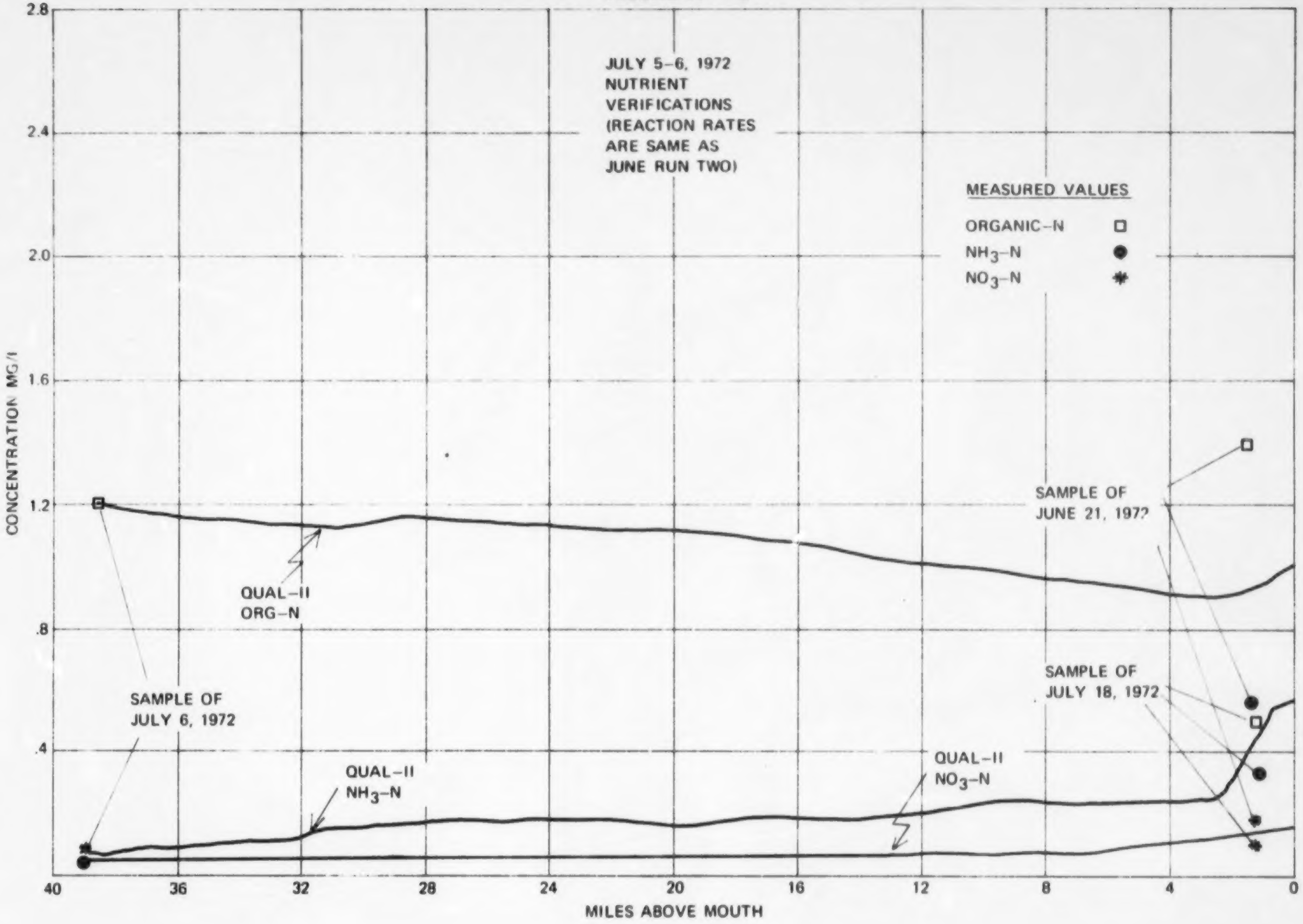

2.8
2.4
2.0
1.6
1.2
.8
.4
CONCENTRATION MG/l
40
36
32
28
24
20
16
12
8
4
0
MILES ABOVE MOUTH
JULY 5–6, 1972
NUTRIENT
VERIFICATIONS
(REACTION RATES
ARE SAME AS
JUNE RUN TWO)
MEASURED VALUES
ORGANIC–N □
NH₃–N ●
NO₃–N ✱
QUAL–II
ORG–N
QUAL–II
NH₃–N
QUAL–II
NO₃–N
SAMPLE OF
JULY 6, 1972
SAMPLE OF
JUNE 21, 1972
SAMPLE OF
JULY 18, 1972

FIGURE IV-9

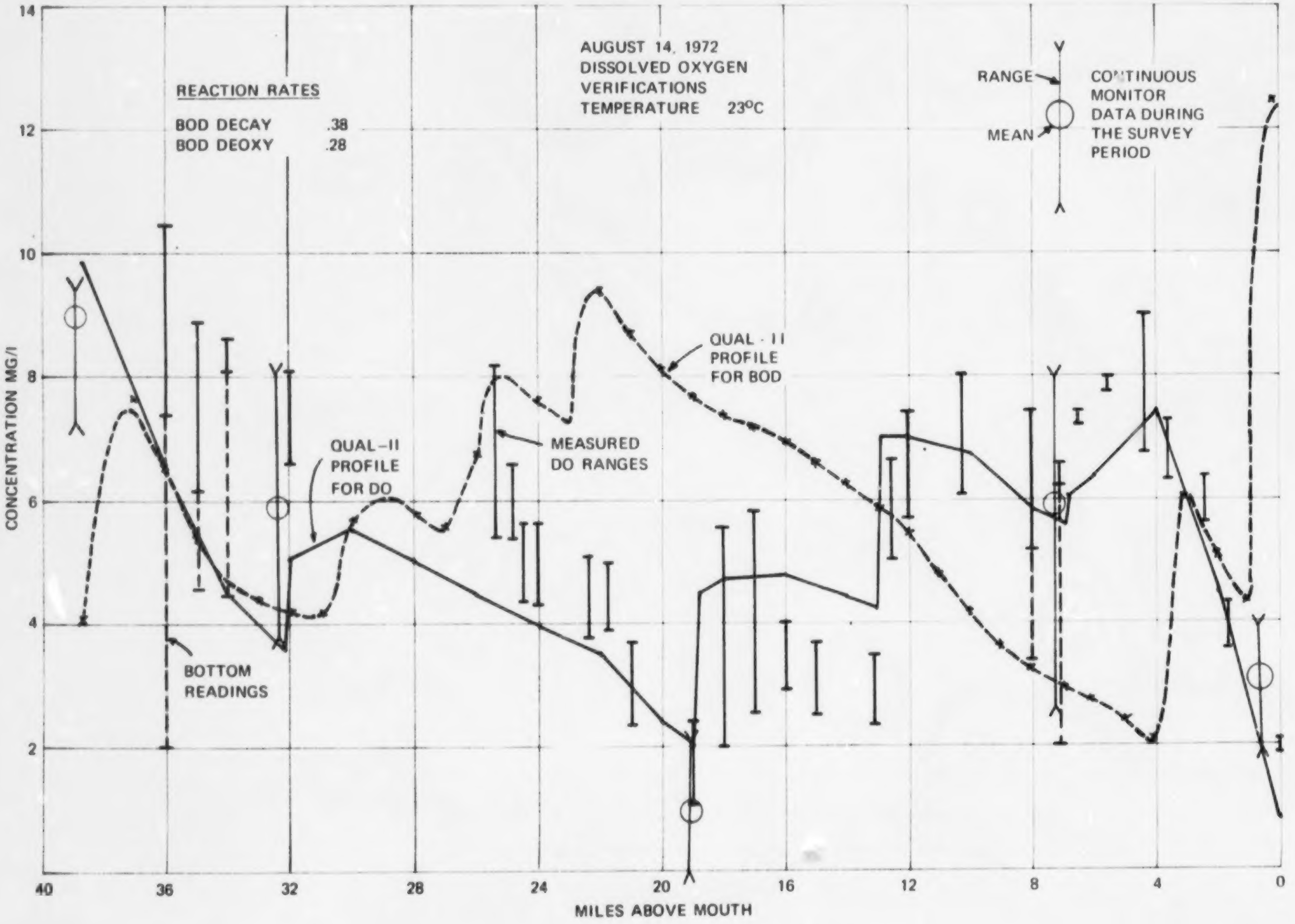
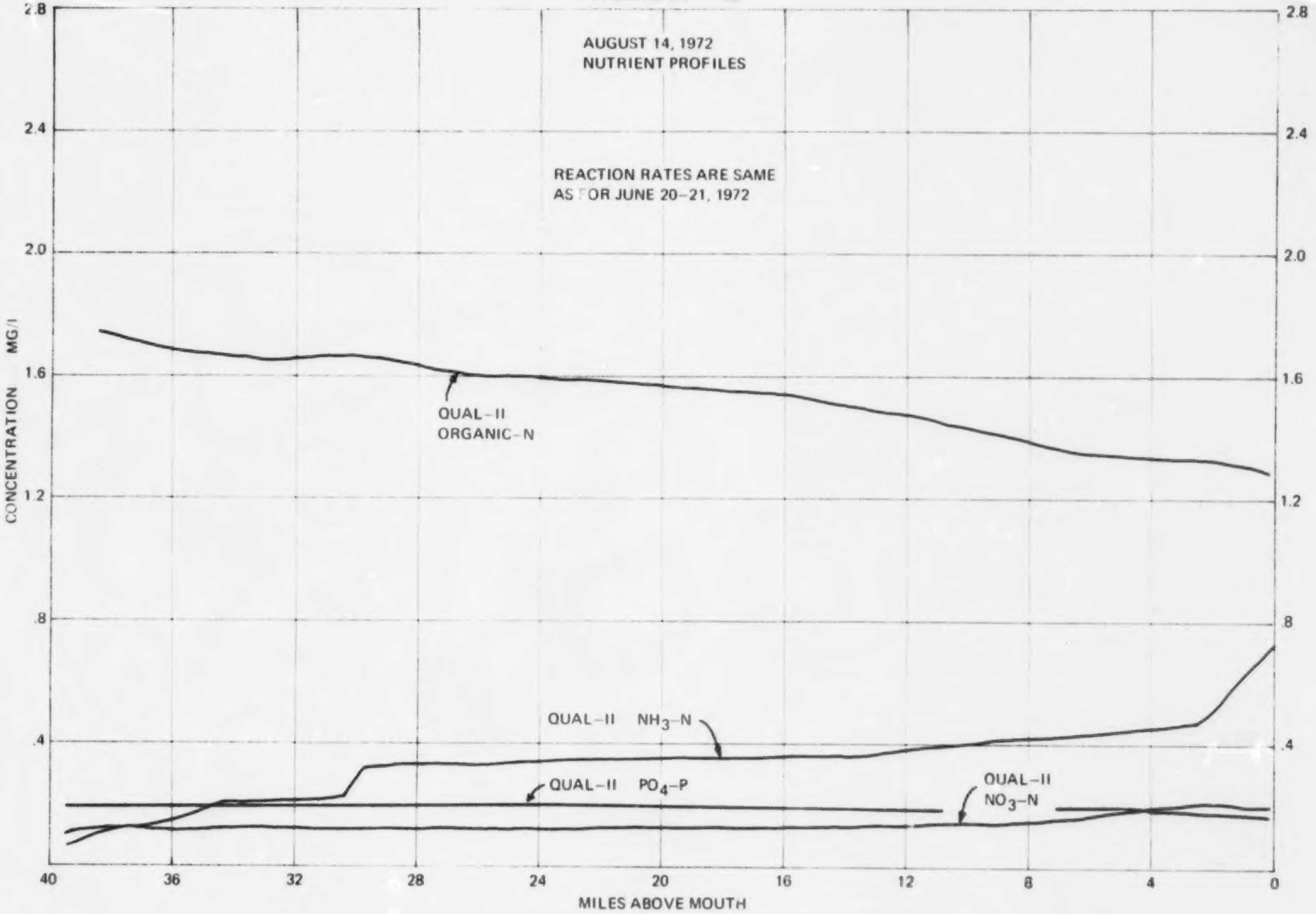

AUGUST 14, 1972
DISSOLVED OXYGEN
VERIFICATIONS
TEMPERATURE 23°C
REACTION RATES
BOD DECAY .38
BOD DEOXY .28
RANGE
MEAN
CONTINUOUS MONITOR DATA DURING THE SURVEY PERIOD
QUAL-II PROFILE FOR DO
MEASURED DO RANGES
QUAL - II PROFILE FOR BOD
BOTTOM READINGS
CONCENTRATION MG/l
14
12
10
8
6
4
2
40
36
32
28
24
20
16
12
8
4
0
MILES ABOVE MOUTH

FIGURE IV – 10


AUGUST 14, 1972
NUTRIENT PROFILES
REACTION RATES ARE SAME
AS FOR JUNE 20–21, 1972
QUAL–II
ORGANIC–N
QUAL–II NH3–N
QUAL–II PO4–P
QUAL–II
NO3–N
CONCENTRATION MG/l
2.8
2.4
2.0
1.6
1.2
.8
.4
40
36
32
28
24
20
16
12
8
4
0
MILES ABOVE MOUTH

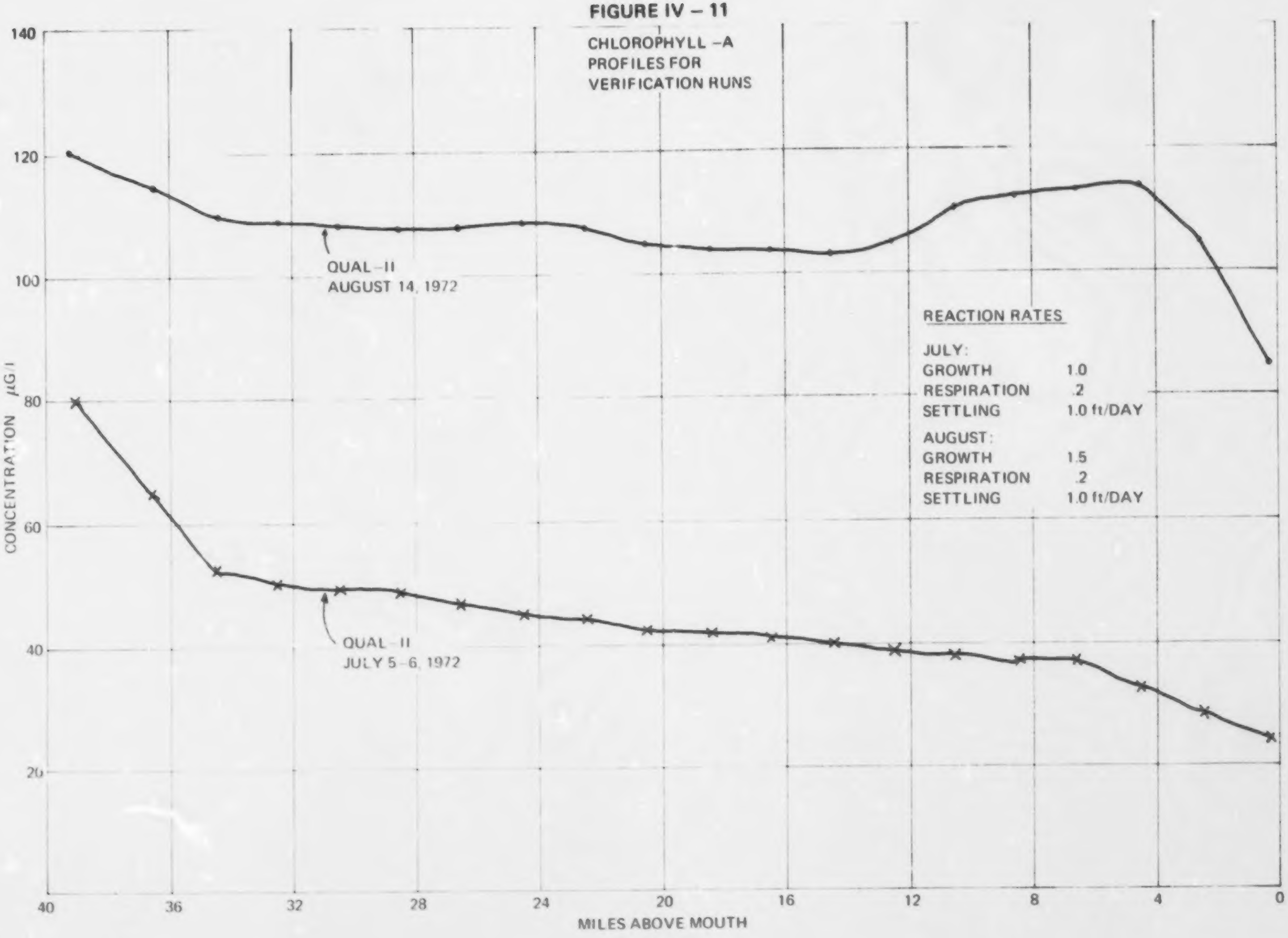


FIGURE IV – 11

CHLOROPHYLL –A
PROFILES FOR
VERIFICATION RUNS

The last constituient to be discussed on the verification runs concerns the chlorophyll-a concentration. Figure IV-5 shows the calculated chlorophyll-a profiles for run one and two on the June 20-21, 1972 verification. Unfortunately there is no data directly available to compare to the chlorophyll-a profile. Thus, no conclusions about the models capability to simulate algae in the Lower Fox River is possible at this time. The best information available for this parameter is a series of chlorophyll-a profiles obtained by Sager and Wiersma during the summer of 1971. The available data is plotted in Figure IV-6. The most apparent trend in the plotted data is a lack of consistency. The profiles were developed from data taken at 10 stations along the Lower Fox River on a biweekly basis. Samples were taken July 28, August 10, August 25, September 7 and September 21. The highest concentrations were obtained on the July 28, 1971 survey. During this survey the upper half of the river had chlorophyll-a levels above 100 ug/l reaching a peak in Little Lake Butte Des Morts of 165.1 ug/l. Only 13 days later, on August 10th the highest observed value was 81 ug/l. Nearly all stations had decreased in concentration by over 50%. The September 7 profile shows a large peak at mile 18.0--nearly 100% larger than any other value taken on that survey. The data represents values of chlorophyll-a in a water sample taken near the surface (1 meter). The model, of course, considers the "well mixed" average concentration over each element. One consistency does appear in all the fluctuations: the dramatic changes in chlorophyll-a concentration in the upper part of the river are not matched by such large fluctuations in the lower half. Thus we observe chlorophyll-a levels in the Menasha area that range from 10 ug/l to 165 ug/l, while at the mouth of the river the range is from 28 to 51 ug/l. The data seems to suggest that the Fox River provides a more stable environment for the phytoplankton. Whereas Lake Winnebago is characterized by periodic blooms and dieoffs during the summer, the entering peaks and troughs of algal activity are distinctly attenuated as the water proceeds toward Green Bay. This attentuation leads to a 50% decrease in chlorophyll-a concentration in general in the downstream direction. This pattern is violated only by isolated peaks along the river and in the area near the mouth of the river. The higher values at the mouth may be a result of seiche effects bringing algal blooms from Lower Green Bay into the river.

It is therefore apparent that we are on tenuous ground in trying to predict algal activity in the Lower Fox River. It appears as if the most significant factor determining the level of algal activity is the amount of algae entering the system from Lake Winnebago. We can however, note one interesting point in a comparison of run one and run two for the June 20-21, 1972 verification. Figure IV-5 indicates a significant change in the chlorophyll-a concentration between the two runs. The only apparent reason for this decrease in algal activity is the concentration of inorganic nitrogen, particularly NO_3-N, which was significantly reduced in run two. It can be concluded from this run that the level of inorganic nitrogen in the Lower Fox River may be an important factor in algal activity! One final point along this line needs to be explained. Denitrification is allowed in QUAL-II and is controlled by the dissolved oxygen level in each computational element. At zero DO, the denitrification rate is maximum at 0.4 day^{-1} (base e). The allowed rate decreased exponentially as the DO rises from zero. One would, of course, expect higher levels of inorganic nitrogen, particularly NO_3-N, under high DO levels. As is shown later, this is in fact what the model predicts. Thus the enthrophication prospects for the Lower Fox River-Green Bay system may be increased, from an inorganic nitrogen point of view, under higher DO levels.

In light of the tremendously wide range of algal activity in the Lower Fox River, it does not make sense to develop a waste load allocation with the expectation that the algal concentration will be continuously adding to the oxygen levels in the stream. One can, however, attempt the waste load allocation such that the algal activity is a low level component in the system. The value of 30 ug/l of chlorophyll-a was used to represent a value well within the range observed but toward the lower end. Under these circumstances, it is reasonable to expect the point source waste loadings to be controlled so no water quality violation is encountered. This is the strategy that was used to develop the waste load allocation for the Lower Fox River that is presented in the next section.

B. Lower Fox River Waste Load Allocation

The QUAL-II model as developed and presented in the section above has shown its usefulness to simulate the Lower Fox River system. Our remaining task is to apply the model under various waste load abatement schemes and evaluate the response of the river system as simulated by the model. The beginning step in this process involves determining the base line conditions that will be used to do the final prediction simulations. This involves determining such parameters as the 7 day, 10 year low flow (7Q10), stream temperature and reaction rates etc.

To determine the 7Q10 low flow, data from the USGS gaging station at Rapid Croche was analyzed for the years 1918 to 1972. The value of 912 CFS was used as a result of this analysis. This flow represents the 7 day low flow that can be expected statistically in any 10 year period. For the low-flow simulations, the flow of 912 CFS was considered to be constant over the entire length of the river. Table IV-2 lists the various parameters that were chosen at the headwater of the system (Lake Winnebago). The value of chlorophyll-a was chosen to reflect a low level of algal activity (for that area) as discussed above. All other values were chosen to reflect typical concentrations that have been observed in the Neenah-Menasha area of Lake Winnebago. Table IV-3 presents an assortment of data collected in this area.

TABLE IV-2

Lake Winnebago Water Quality Used for the QUAL-II Prediction Simulation Runs of the Lower Fox River

Parameter	Concentration
FLOW	912.0 CFS
Dissolved Oxygen	8.00 mg/1
BOD (5-day)	2.00 mg/1
Organic-N	2.50 mg/1
NH_3-N	0.05 mg/1
NO_2-N	0.001 mg/1
NO_3-N	0.10 mg/1
Tot. PO_4-P	0.20 mg/1
Chlorophyll-a	30.0 ug/1
Temperature	80°F

TABLE IV-3

Water Quality Parameters Measured in the Neenah-Menasha Area of Lake Winnebago on various dates

Parameter	May 4, 1972	June 21, 1972	July 6, 1972	Oct. 23, 1974	Nov. 11, 1974
DO mg/1		13.0		11.2	10.1
BOD mg/1				1.8	2.0
Org-N mg/1	.89	2.5	1.2	.64	.55
NH_3-N mg/1	.02	.04	.03	.29	.15
NO_2-N mg/1	.002	.010	.004	.23	.33
NO_3-N mg/1	.1		.05		
TOT. PO_4-P mg/1		.22	.1	.15	.09
Sol. PO_4-P mg/1		.01	.02	.092	.07
Temperature °C		20.		8.0	7.0
pH	8.0			8.4	8.2
Chloride mg/1				7.0	8.0
Color su				15.0	20.0
Suspended Solids mg/1		29.0		9.0	5.0

The design termperature for all prediction runs was 80°F. This temperature was selected to reflect the data obtained from the five automatic monitoring stations that have been operated since 1971. Daily maximum temperatures at all five stations (Menasha, Appleton, Rapid Croche, De Pere, Green Bay), exceed 80°F during July and August of all years since the monitors have been operated. Some maximums have gone as high as 84°F.

The benthic oxygen demand used in the simulation runs were calculated on the basis of suspended solids discharged. The verification runs for June 20-21, 1972, July 5-6, 1972 and August 14, 1972 all were run with the same benthic oxygen demand pattern. The values appear in Table IV-1 along with benthic oxygen demand values for BPT conditions. The projected percent reduction in discharged suspended solids at each point source was used to reduce the benthic oxygen demand in the affected reaches by an equal percent. As the BOD_5 and suspended solids loads were reduced in the process of finding a set of discharge conditions that would meet 5.00 mg/1 of oxygen, the benthic demand was again reduced by a corresponding amount in the appropriate reaches. Table IV-4 summarizes the projected reduction in suspended solids in the various segments of the Lower Fox River.

Prediction Simulations

The conditions discussed above were used to generate a simulation run of the Lower Fox River for Best Practicable Treatment levels and low flow (912 CFS) conditions. Table IV-5 lists inputs for each waste source considered in the model for this run. Figures IV-12 and 13 display the QUAL-II predicted profiles. It should also be made clear that Figure IV-12 represents the daily average dissolved oxygen level and does not give any information concerning the daily fluctuation from algae activity.

TABLE IV-4

Projected Suspended Solids Reductions Used to Determine Benthic Oxygen Demands under "Best Practicable Treatment" Levels

	Suspended Solids (lb.day)	
Dischargers	Present	BPT
Neenah-Menasha Area (Reaches 1 - 9)		
Neenah-Menasha STP	22500.	5000.
K. C. Lakeview	940	1100.
K. C. Neenah	2037.	1025.
K. C. Badger Globe	----	
George Whitting	1635.	200.
Bergstrom	18000.	3628.
Wisconsin Tissue	----	1602.
Menasha Sanitary District #4	50.	50.
TOTAL	45162.	12623.
% Reduction		72%
* * * * *		
Appleton Area (Reach 10-16)		
Riverside Paper	976.	830.
Cons. Paper	10420.	1200.
Appleton STP	20000.	4100.
TOTAL	31396.	6130.
% Reduction		81%
* * * * *		
Kimberly Area (Reach 17-18)		
K. C. Kimberly	12246.	3000.
% Reduction		76%
* * * * *		
Combined Locks (Reach 19-21)		
Appleton Papers	6758.	4130.
% Reduction		39%

* * * * *

TABLE IV-4 (continued)

Kaukauna Area (Reach 22-24)

Thilmany Paper	9803.	5900.
% Reduction		40%

* * * * *

(Reaches 25-34 have no significant discharges)

* * * * *

De Pere Area (Reach 35-38)

Nicloet Paper	472.	972.
De Pere STP	2160.	1185.
TOTAL	2632.	2157.
% Change		18%

* * * * *

Green Bay Area (Reach 39-46)

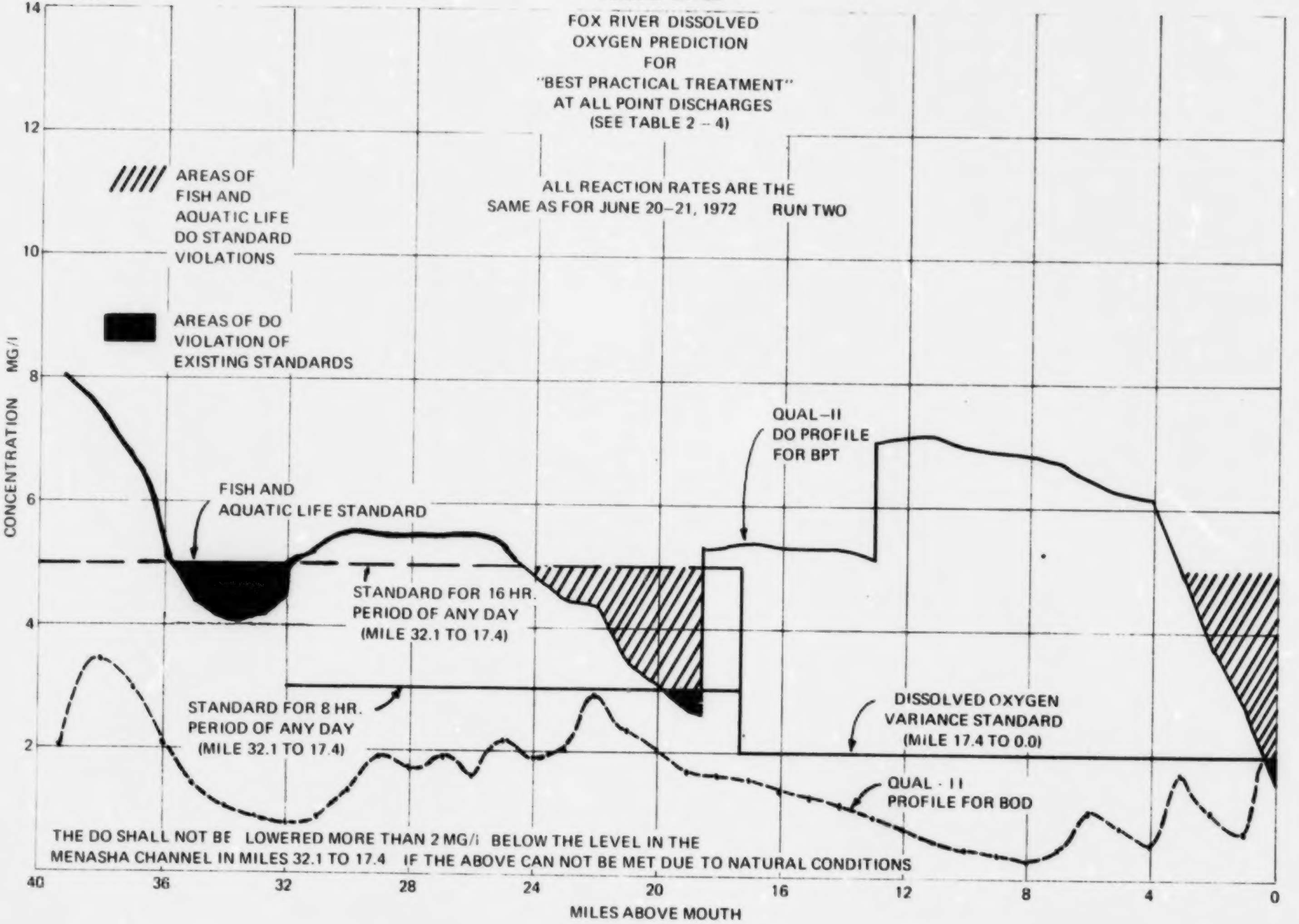
Fort Howard	20000.	12900.
Charmin	14983.	4140.
Green Bay Packaging	343.	1200.
American Can	6761.	8500.
Green Bay STP	23000.	13100.
TOTAL	65087.	39840.
% Reduction		39%

TABLE IV-5

Final Permit (1977) Loadings for Lower Fox River Waste Sources

Source Name	BOD_5 kg/day (lbs/day)	Suspended Solids kg/day (lbs/day)
K. C. Neenah & Badger Globe	498.9 (1100)	464.8 (1025)
Bergstrom Paper	1077.1 (2375)	1645.3 (3628)
K. C. Lakeview	816.3 (1800)	498.9 (1100)
Neenah Menasha STP	2043.5 (4506)	2043.5 (4506)
Wisconsin Tissue	536.9 (1184)	726.5 (1602)
Menasha Sanit. Dist. E. & W.	359.6 (793)	359.6 (793)
Riverside Paper	394.5 (870)	376.4 (830)
Formost Dairy	49.0 (108)	----NA----
Consolidated Appleton	1133.8 (2500)	680.3 (1500)
Appleton STP	1859.4 (4100)	1859.4 (4100)
K. C. Kimberly	907.0 (2000)	1360.5 (3000)
Appleton Papers	1655.3 (3650)	1873.0 (4130)
Heart of the Valley STP	601.8 (1327)	601.8 (1327)
Thilmany Paper	2675.7 (5900)	2675.7 (5900)
Wrightstown STP	73.5 (162)	73.5 (162)
Nicolet Paper	589.6 (1300)	440.8 (972)
De Pere STP	1614.0 (3559)	1614.0 (3559)
Fort Howard Paper	3945.5 (8700)	5850.0 (12900)
Charmin Paper	3460.2 (7630)	3854.8 (8500)
Green Bay Packaging	725.6 (1600)	544.2 (1200)
American Can	839.0 (1850)	571.4 (1260)
Green Bay STP	5940.9 (13100)	5940.9 (13100)
TOTAL	31,797.3 (70115.)	34,082.1 (75153)

FIGURE IV-12



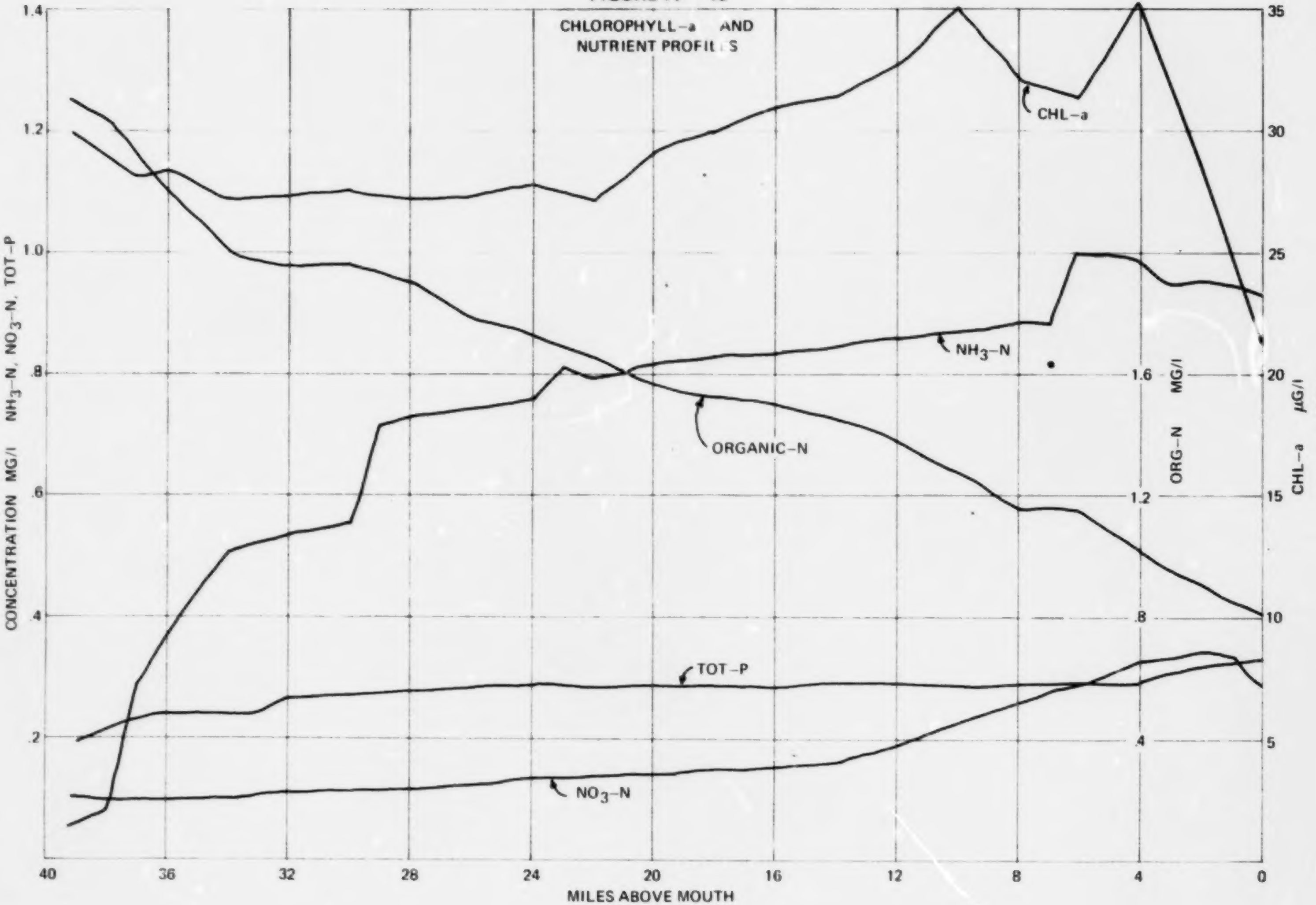
FOX RIVER DISSOLVED
OXYGEN PREDICTION
FOR
"BEST PRACTICAL TREATMENT"
AT ALL POINT DISCHARGES
(SEE TABLE 2 – 4)

ALL REACTION RATES ARE THE
SAME AS FOR JUNE 20–21, 1972 RUN TWO

THE DO SHALL NOT BE LOWERED MORE THAN 2 MG/l BELOW THE LEVEL IN THE MENASHA CHANNEL IN MILES 32.1 TO 17.4 IF THE ABOVE CAN NOT BE MET DUE TO NATURAL CONDITIONS

FIGURE IV – 13

CHLOROPHYLL–a AND NUTRIENT PROFILES

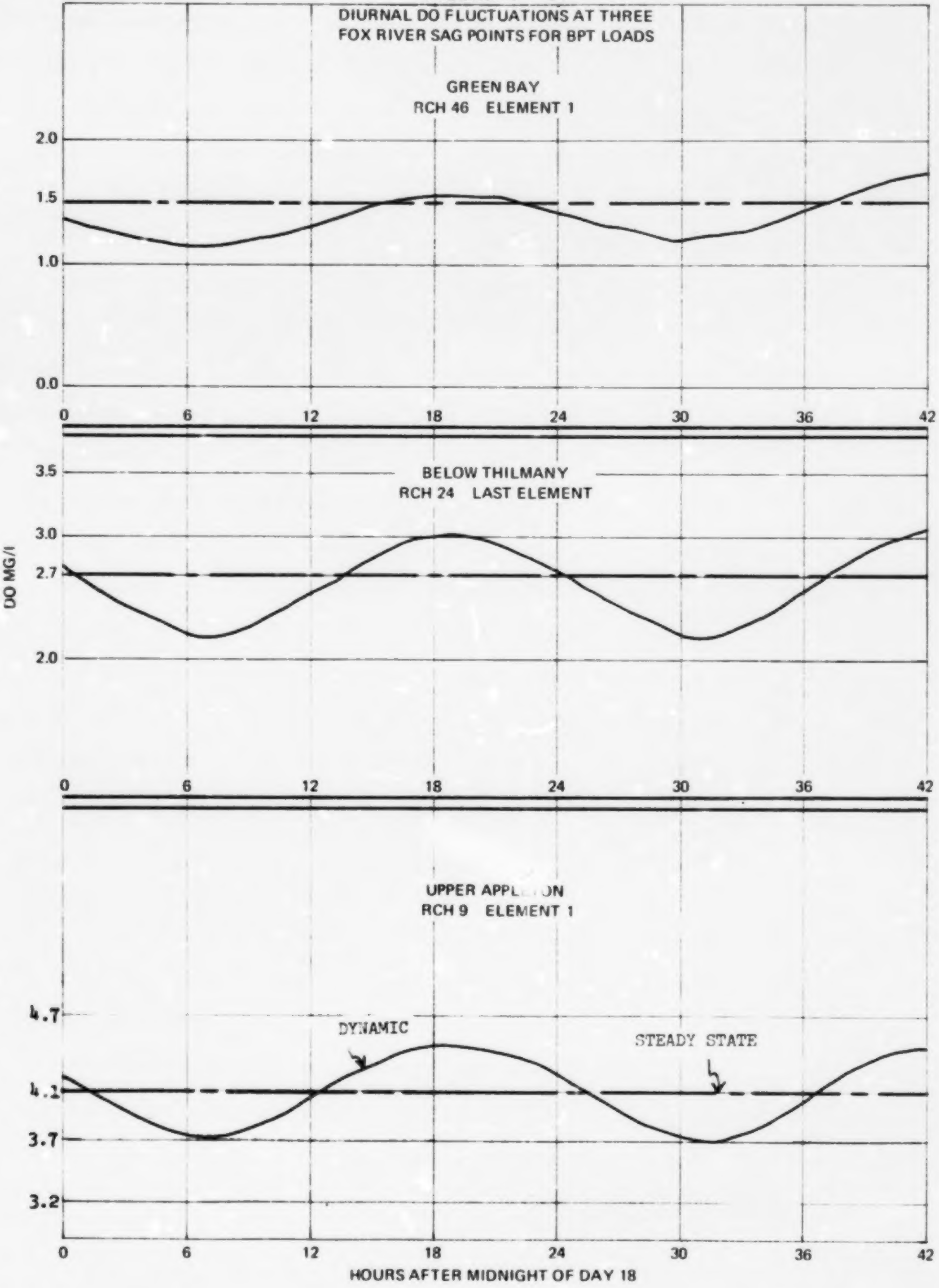


As can be seen, significant violations of the 5.00 mg/l dissolved oxygen level for fish and aquatic life occur at 3 locations along the river. In addition all three DO sag areas will violate the current standard for dissolved oxygen. A dynamic simulation run was also done for the BPT condition. (BPT is used in this report to refer to the discharge levels to be attained by the end of 1977. In some cases the permits are slightly lower than BPT but in general they represent Best Practicable Technology.) A portion of the results are presented in Figure IV-14. This run shows that the dissolved oxygen would be expected to vary by as much as 1.0 mg/l. In the Menasha, Kaukauna and Green Bay areas this could lower the DO below 3.0, 2.5 and 1.0 mg/l respectively during nighttime hours. Under such circumstances the applicable variance conditions for DO in these areas would be violated. It is clear from these results that the wasteloads under BPT conditions will generate water quality violations in at least three areas along the river. If we compare the predicted DO profile to the fish and aquatic life standard of 5.0 mg/l we find that nearly 15 miles of the river would be below this level on a daily average basis! AS mentioned above, nighttime conditions will greatly enlarge the area and extent of those violations. On the basis of the above results, it can be concluded that "best practicable treatment" for all point sources on the Lower Fox River will not achieve a minimum level of dissolved oxygen necessary to sustain most fish and aquatic life.

The level of treatment required to meet a DO standard of 5.0 mg/l was determined using the model in a fashion similar to that described above. The steady state version was applied for this purpose. Initial conditions were as shown in Table IV-2. The procedure followed to generate the waste load allocation consisted of reducing the appropriate discharges (BOD_5 and suspended solids) from those sources that were directly upstream from a given sag in the DO (See Figure IV-12). Each such discharger was reduced by a flat percentage. The BOD_5 and the

FIGURE IV – 14

DIURNAL DO FLUCTUATIONS AT THREE FOX RIVER SAG POINTS FOR BPT LOADS



suspended solids were reduced by equal percentages. The percent reduction in the benthic oxygen demand was then recalculated on the basis of the new discharges and those figures were entered in the model. The QUAL-II model was then executed and the results were screened for any remaining violations. This procedure was repeated if required.

In this way, various point source effluents were reduced until a profile was obtained that did not violate the 5.0 mg/l requirement for dissolved oxygen on a daily average basis. The results of this procedure are presented in Table IV-6 and Figures IV-15 and 16. The effluents for this procedure assumed no change in the discharge of nitrogen and phosphorous compounds. A second run (Run B) was then made assuming nitrification was installed at all sewage treatment plants and phosphorous removel to 1.00 mg/l was accomplished for all dischargers. The effluents under this condition assumed the following discharges for all sewage treatment plants:

Organic N - 2.00 mg/l
NH_3-N - 1.00 mg/l
NO_3-N - 3.00 mg/l
TOT-P - 1.00 mg/l

The results for this run are shown in Figures IV-15 and 17. As can be seen in Figure IV-15, ammonia reduction at all STP does not alter the DO profile. The DO was changed by about 0.05 mg/l in most areas. A comparison of Figures IV-16 and 17 reveals a definite reduction of NH_3-N (by as much as 0.2 mg/l) and a corresponding increase in the concentration of NO_3-N (by as much as 0.1 mg/l). The concentration of NH_3-N still, however, attains concentrations in the Green Bay

TABLE IV-6

Waste Load Allocation Loadings for the Lower Fox River Determined by QUAL-II Simulation to Maintain 5.0 mg/l of Dissolved Oxygen

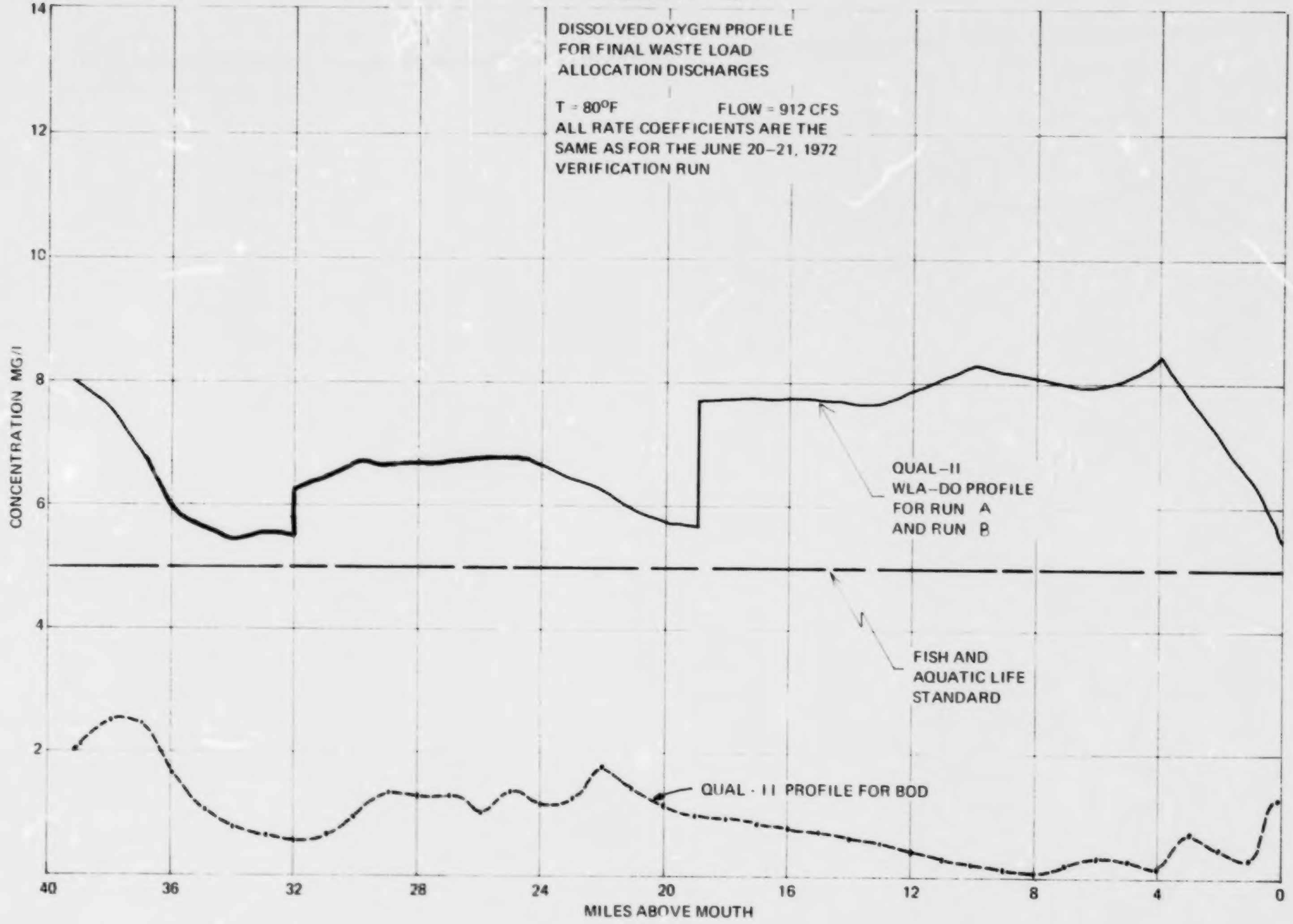
Discharger	BOD$_5$		Suspended Solids	
	kg/day	lbs/day	kg/day	lbs/day
Kimberly Clark Neenah Badger Globe	424.0	935.	395.0	871.
Bergstrom Paper	915.6	2019.	1398.2	3083.
Kimberly Clark Lakeview	693.9	1530.	424.0	935.
Neenah Menasha STP	1737.0	3830.	1737.0	3830.***
Wisconsin Tissue	456.2	1006.	617.2	1361.
Menasha Sanitary District E. & W.	305.7	674.	305.7	674.***
Riverside Paper Co.	268.0	591.	256.2	565.
Formost Dairy	49.0	108.	----------NA----------**	
Consolidated, Appleton	771.0	1700.	462.6	1020.
Appleton STP	1237.6	2729.	1237.6	2729.*
Kimberly Clark, Kimberly	616.8	1360.	925.1	2040.
Appleton Papers	983.2	2168.	1276.6	2815.
Heart of the Valley STP	401.3	885.	401.3	885.*
Thilmany Papers	1546.4	3410.	1546.4	3410.
Wrightstown STP	49.0	108.	49.0	108.*
Nicolet Paper	290.2	640.	163.3	360.
De Pere STP	537.4	1185.	537.4	1185.**
Fort Howard Paper	2040.8	4500.	2267.5	5000.
Charmin Paper	1632.6	3600.	2176.8	4800.
Green Bay Packaging	580.5	1280.	435.4	960.
American Can	544.2	1200.	544.2	1200.
Green Bay STP	3960.4	8733.	3960.4	8733.*
TOTAL	20040.8	44191.0	21116.9	46564.0
% Below BPT	37%		38%	

* Based on 20 mg/l for Design Flow

** Based on 10 mg/l for Design Flow

*** Based on 25.5 mg/l for Design Flow

FIGURE IV – 15



DISSOLVED OXYGEN PROFILE FOR FINAL WASTE LOAD ALLOCATION DISCHARGES

T = 80°F FLOW = 912 CFS

ALL RATE COEFFICIENTS ARE THE SAME AS FOR THE JUNE 20–21, 1972 VERIFICATION RUN

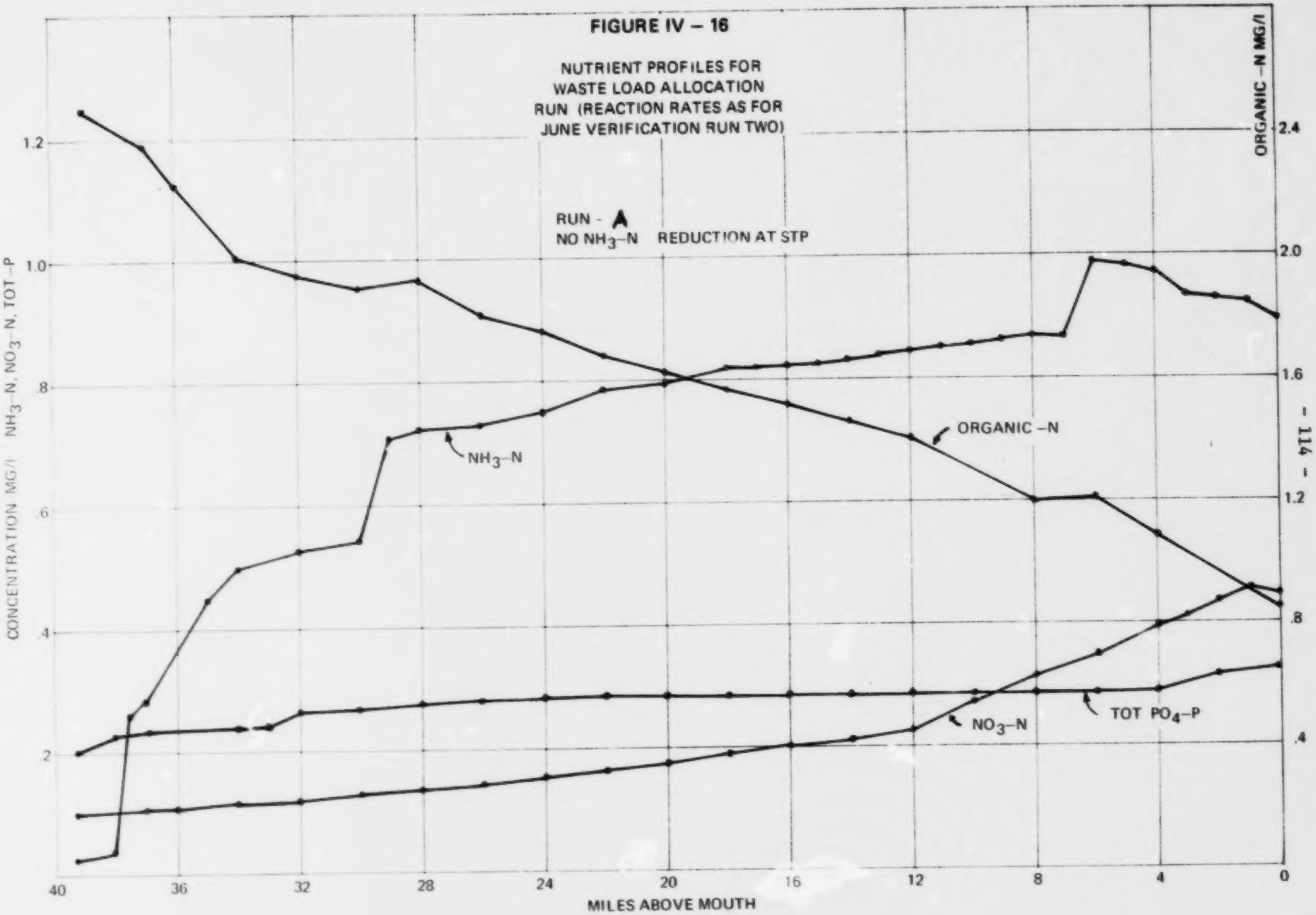


FIGURE IV – 16

NUTRIENT PROFILES FOR WASTE LOAD ALLOCATION RUN (REACTION RATES AS FOR JUNE VERIFICATION RUN TWO)

RUN - A
NO NH_3–N REDUCTION AT STP

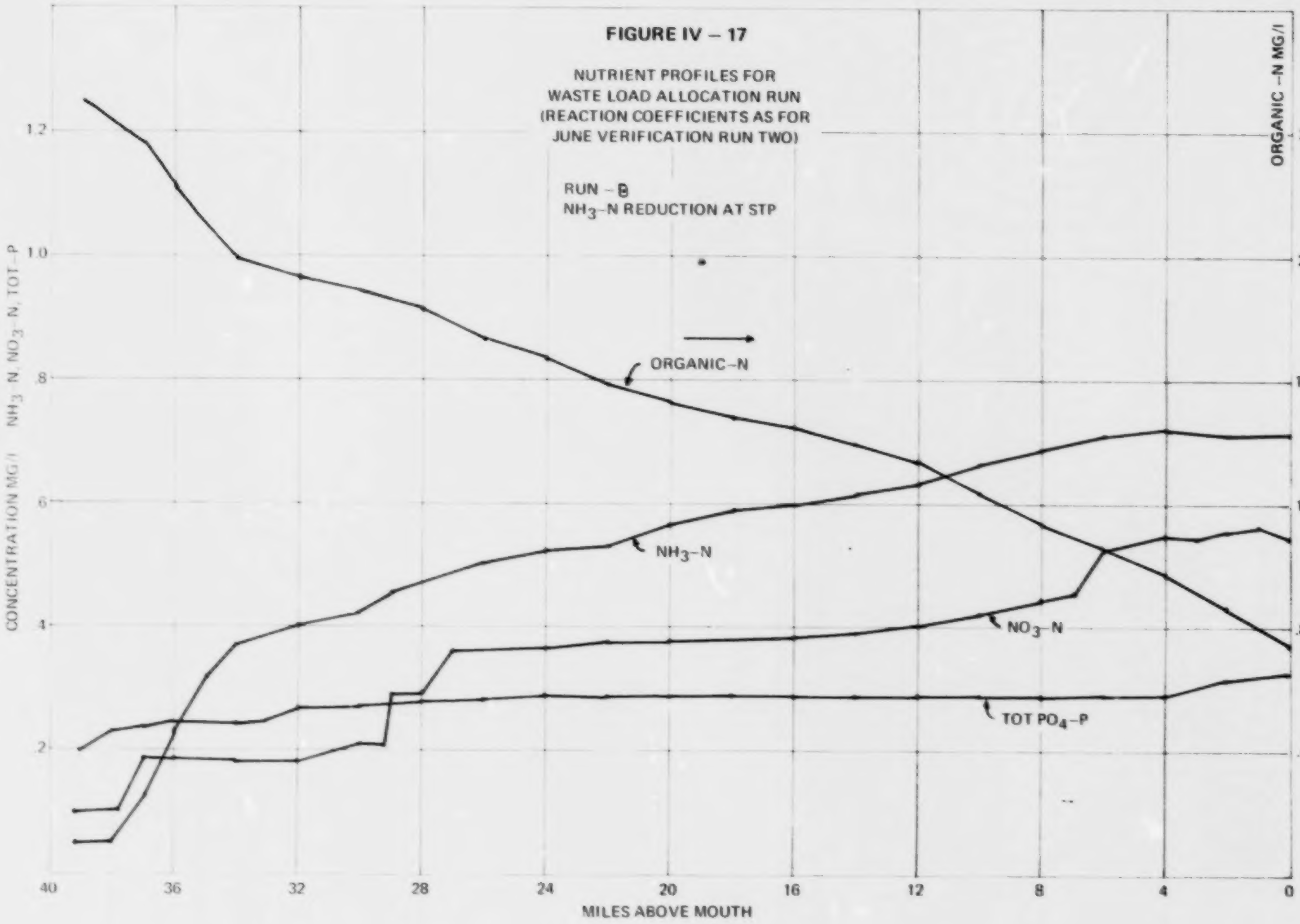


FIGURE IV – 17

NUTRIENT PROFILES FOR
WASTE LOAD ALLOCATION RUN
(REACTION COEFFICIENTS AS FOR
JUNE VERIFICATION RUN TWO)

RUN – B
NH_3–N REDUCTION AT STP

area as high as 0.72 mg/l. This would tend to indicate that the most significant source of NH_3-N (according to the model) is the hydrolysis of organic nitrogen. This conclusion is supported by the high levels of NH_3-N observed on the June 20-21, 1972 survey (Figure IV-4). An ammonia level of 0.72 mg/l will be toxic to fish life if the pH is greater than 8.0 and the temperature is greater than 20°C. Since the pH of the Fox River frequently exceeds 8.0, ammonia toxicity may be a continuing water quality problem even if nitrification is accomplished at all sewage treatment plants. Further-more, since the DO profile shows little response to nitrification at the treatment plants, it appears as if there is little reason to pursue nitrification as a viable means of improving the water quality of the Lower Fox River at this time. If, however, higher DO levels significantly increase the nitrification potential, a dissolved oxgyen deficit of significance may occur. This is not likely though unless the pH of the river experiences a long term change to a lower level. According to Srinath (et al 1974) nitrification is markedly inhibited at pH's above 8.0. Typical pH values for the Fox River range from 8.0 to as high as 9.2.

The model simulations discussed above concerning ammonia must be taken as preliminary only and no conclusions should be based on them. In view of the lack of good data for ammonia both from the sewage treatment plants and in the river (and a few wood pulping operations) the main source of the ammonia in the Lower Fox River cannot be definitely determined. Three sources can be significant contributers: 1) point source discharges, 2) organic nitrogen entering from Lake Winnebago that hydrolyzes to ammonia as it travels downstream and 3) sediment release. It would be beneficial to monitor ammonia and total organic nitrogen at all sewage treatment plants and any significant industrial dischargers. This type of monitoring could be made a part of each discharger permit. Until such data is available and in light of the modelling results, no allocation of ammonia (or Kjeldahl nitrogen) can be made.

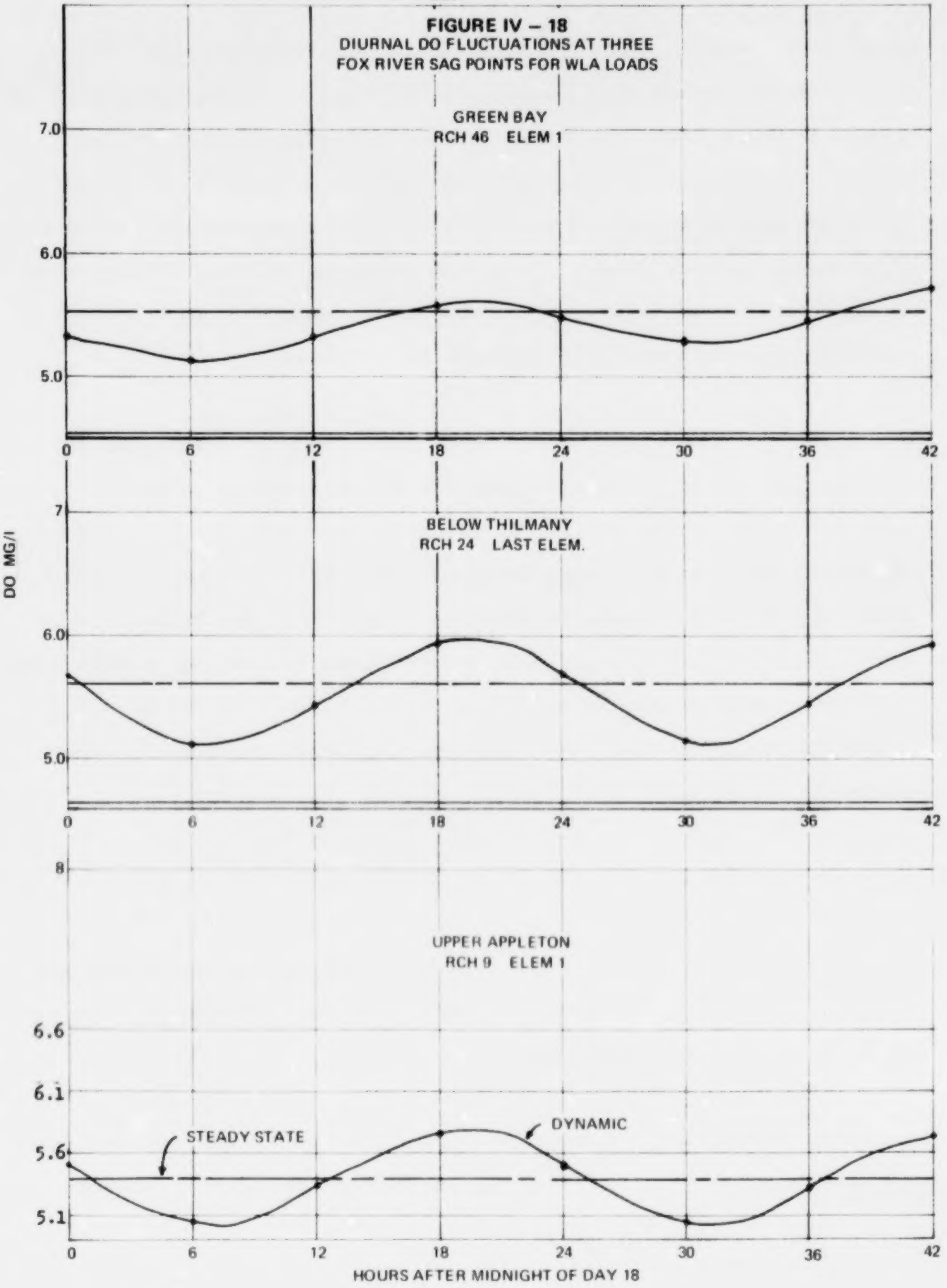


FIGURE IV – 18
DIURNAL DO FLUCTUATIONS AT THREE
FOX RIVER SAG POINTS FOR WLA LOADS

To answer the question of algae effects a dynamic run was done for the waste load allocation and reduced NH_3-N loading configuration. A portion of that output appears in Figure IV-18. The plots of diurnal DO fluctuations indicate that the DO will not violate 5.00 mg/l under the simulated conditions even during the lowest point on the duirnal cycle. It should be emphasized, however, that this does not preclude the possibility of DO standards violations. A high level of algae (from a summer bloom) coupled with several consecutive days of very little sunlight could possibly bring the DO below 5.00 mg/l.

With all of the above in mind, it can be concluded that the waste loadings for BOD_5 and suspended solids shown in Table IV-6 should be expected to meet 5.0 mg/l of DO in the Fox River under low flow (912 CFS) conditions. Furthermore, it does not appear to be necessary to require nitrification at sewage treatment plants as a means of improving the dissolved oxygen. The concentration of NO_3-N can be expected to rise slightly as a result of higher DO levels which will suppress denitrification. Finally, the listed WLA loadings represent an average of 37% and 38% reduction over "best practicable treatment" levels for BOD_5 and suspended solids respectively.

C. Green Bay Modelling

As part of this project, a water quality model of Green Bay was developed. The purpose of this model was to develop a predictive capability of the water quality of the lower one-third of Green Bay. The model chosen for this activity was based on the Dynamic Estuary Model developed by Water Resources Engineers. This model was originally developed for San Francisco Bay and was later modified for use with Pearl Harbor. The model was obtained by DNR from WRE in February of 1974. In the process of fitting the model to the Green Bay situation, extensive modifications were made. A complete description of the model as used in the Green Bay modelling effort is contained in Appendix D. Flow charts and program listings along with a data set up description are included.

Two main areas of use were intended for the Green Bay model (GBQUAL). First, information regarding the response of Green Bay under ice cover was a prime concern. Surveys of 1939, 1955, 1967 and 1974 (part of this project) all showed extensive areas of low to zero dissolved oxygen during the ice cover period. For Green Bay, the period of ice cover may range from two to three and one half months. Ice cover usually begins in early January. The low dissolved oxygen levels have hindered commercial fishing operations over as much as 150 square miles of the Lower Bay. This region begins below a line from Long Tail Point to Point Sable and can extend along the eastern half of the bay to beyond the Renard River. A question that has received particular attention in this report is: what level of treatment for point source discharges along the Lower Fox River will be required to eliminate this problem?

The second main emphasis concerns the eutrophic nature of the Lower Bay. Highly fertile water from the Lower Fox and other rivers have been contributing vast quantities of nutrients (particularly nitrogen and phosphorous). These nutrients enhance the growth of phytoplankton causing nuisance algae blooms throughout the summer. These blooms are unpleasant from an aesthetic standpoint and serve to severely limit the recreational uses of the Lower Bay. They also may be partly responsible for taste and odor problems in water supplies taken from Bay water further north. To remove these effects requires a significant expense at water treatment facilities.

Winter Modelling of Green Bay

Winter conditions in Green Bay complicate the water quality problems of the Bay. Severely cold temperatures in Wisconsin normally serve to form an ice cover on Green Bay from early January to as late as early April. The ice cover may grow to a depth of 4 feet. This ice cover effectively shuts off any available reaeration that would otherwise maintain high dissolved oxygen levels. If the ice is covered by an additional layer of opaque snow, any small amount of photosynthesis that may take place will also be virtually eliminated. Under these conditions, the only remaining source of oxygen is the inflowing water from the major tributaries.

The Lower Fox River, during December to April, enters the bay carrying about 8-14 mg/l of dissolved oxygen. Unfortunately, this river water also carries with it a high load of organic compounds from the numerous dischargers along the Fox River. Nearly all of this organic load is capable of exerting an oxygen demand on the Bay water and this oxygen demand severely strains the limited oxygen resources of the ice-covered Lower Bay.

The temperature of the ice-covered Bay water ranged from 0.0°C to 3.0°C. At this low temperature, chemical and biological reactions take place at very decreased rates; however, the reactions do not stop conpletely. The long-term BOD of organically rich water incubated at low temperatures can be significant. Two important problems come to the fore at this point. First, we need to have the ability to predict the long term effect of organic wastes carried in the river water. It is clear from data obtained from various Green Bay winter surveys that the dissolved oxygen depletion develops over an extended period of time. This analysis reveals that the customary 5-day BOD test is inadequate to supply information of oxygen consumption that may take place over a 60 to 90 day period. The second important aspect of this problem involves the choice of the rate constants required to properly describe the low temperature BOD uptake. Both of these problems have been investigated by the author and the results are presented below.

Figure IV-19 illustrates a curve for a long term BOD test on a sample taken from the mouth of the Fox River. This curve shows the laboratory oxygen demand as a function of time over a 60 day period (slightly less than the length of time Green Bay is ice-covered during a normal winter). This curve is interesting for several reasons. First, it shows that the 60 day BOD is considerably greater than the 20 day BOD (frequently considered the ultimate) and is in fact nearly 4 times as great as the 5-day BOD. Secondly, this curve indicates that although the rate of oxygen consumption is slowing, it is clearly not stopping, even after 60 days! If we attempt to fit this data to a typical BOD equation we immediately discover that it is nearly an impossible task. Either we fit the data precisely for the first 5 to 10 days and severely underestimate the ultimate BOD or we can fit the ultimate range correctly but we can no longer follow the curve exactly.

We are left with the choice: To which portion of the curve can we sacrifice accuracy? The answer, of course, is that we can fit both ends by merely including more terms in the BOD equation. If we write the BOD equation as:

$$L = \sum_{i=1}^{3} L_i \left(1 - e^{-k_{1i} t}\right) \tag{1}$$

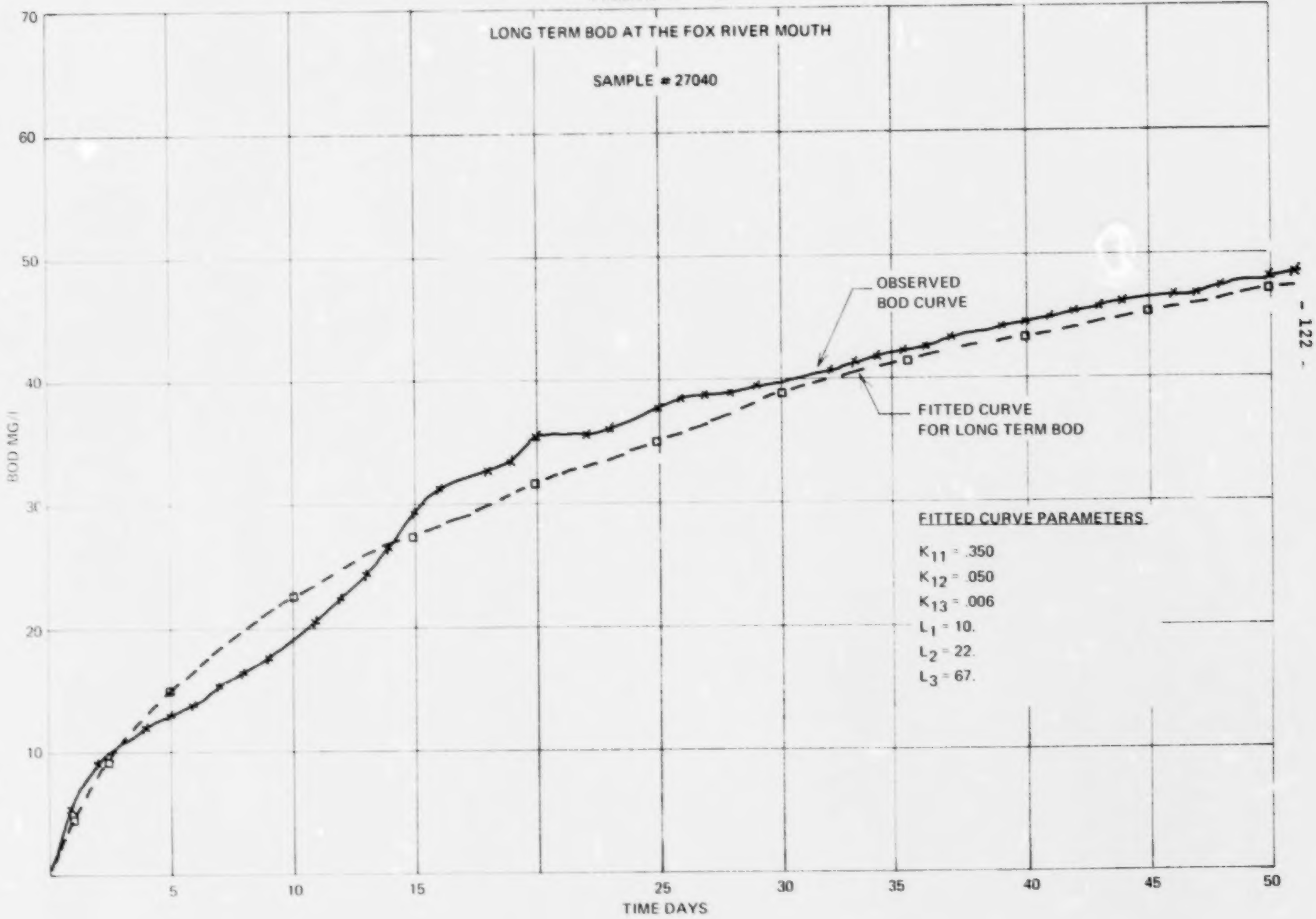
where: L = BOD mg/l

L_i = seperate ultimate BOD's for each term

k_{1i} = respective decay rates day^{-1} (base e)

t = time (days)

FIGURE IV – 19



LONG TERM BOD AT THE FOX RIVER MOUTH

SAMPLE # 27040

Each term is assumed to start at time zero but to proceed at a different rate and aim toward a different ultimate. Figure IV-19 shows how this curve can be fit with a three term equation. As can be seen, each term in the equation reacts with a much slower decay rate than the preceding terms. This in effect extends the time over which the total ultimate BOD is reached.

In theory this type of approach is separating the waste material into three individual components and assigning a different decay rate to each. Each component's percent of the total waste strength is reflected by its ultimate term.

The decay rates for term two and three are usually at least an order of magnitude less than that for the first term. This implies that under normal circumstances the last two terms contribute so little to the oxygen deficit that they can be effectively ignored. However, there is an important case when this is not true. Under ice conditions, the reaeration rate is effectively lowered to nearly zero. As long as this condition exists, any exerted oxygen deficit will accumulate. It is obvious that under such a condition, the effect of the last 2 terms in equation IV-1 can be significant.

The above problems are compounded by the fact that very little long term BOD sampling has taken place at the mouth of the Lower Fox River. There are several reasons for this. First, until recently, the 5-day BOD measured at the Green Bay Monthly Monitoring Station was believed to be adequate to characterize the strength of the waste entering the Bay. This is true if the required information is merely relative strength of the oxygen demand. The discussion above indicates why a precise long-term BOD is required. Secondly, a severe sampling problem exists at the mouth of the Lower Fox River. The monthly monitoring station in Green Bay is directly upstream of four large dischargers in the Green Bay area. Thus, the effects of their waste on Green Bay is not included in the monthly monitoring data. This problem will be further complicated by the new Green Bay sewage treatment plant since the discharge location is actually a few hundred feet into the Bay directly off the end of the Lower Fox River. Therefore, any data on pollution loading to Green Bay from the Lower Fox River will at least be an estimate.

The first attempts to simulate the under-ice DO sag observed in Green Bay used a single term BOD equation. It became apparent that not enough oxygen deficit could be generated for the observed 5-day BOD and a normal conversion to ultimate (usually 1.6 to 1.). (A single term BOD equation with a decay rate of 0.20/day will yield a rate of BOD ult. to BOD_5 of 1.58.) To account for this difference, the benthic oxygen demand was adjusted until the observed sag was generated. The result was a set of unrealistically high benthic oxygen demands. Laboratory and field data both have indicated benthic demands at a relatively low level (see Appendix C-Benthic Oxygen Demand). All measurements yield numbers in the range of .05 to 2.0 GR O_2/m^2/day with a mean of about .2 GR O_2/m^2/day at 20°C. Faced with this discrepancy, it was concluded that more attention had to be paid to the "tail end" effects of the long-term BOD data. The three term BOD supplied the required "tail end" effects.

It should be noted at this point that the effects predicted by the above described BOD formulation may imply that significant reduction of short term BOD will not change the long term BOD by a corresponding percentage. It is very possible that a treatment system that effectively removes 90% of the 5-day BOD may only be removing 50% of the ultimate BOD. In other words a 90% reduction in short term BOD may yield far less improvement than at first expected. All is not lost however. The slower rates for decay of the last terms indicate that the time in which the sag develops will be greatly increased, thus allowing considerably more time for natural diffusion and dilution to decrease the strength of the waste before severe depletion can occur. The above discussion reveals that the effects of "Best Practicable Treatment" are not at all clear without some improvements in the modelling techniques used to describe the system interaction

Faced with the above problems, an attempt was made to model the system using a three term BOD equation. In terms of the computer model, this addition was quite simple. This was done simply by writing parallel equations for each BOD term. The difficulty in this approach lies in the fact that we now are dealing with six unknowns instead of two (3 K rates and 3 ultimates). To facilitate selection of the 6 unknowns, a simple computer program was devised that used an iterative method to fit a given long term BOD curve such as Figure IV-19. The long term curve fitting program selected the K rates and ultimates shown. As can be seen, the fit is quite close to the observed BOD curve. Kjeldahl nitrogen in the long term BOD of Figure IV-19 was near 1.0 mg/l. The nitrogen component of the BOD was therefore less than 5.00 mg/l.

The second problem mentioned above involves the selection of temperature correction coefficients. The BOD decay rates are input to the model assuming 20°C. The model internally adjusts each decay rate for the simulation temperature. The correction equation takes the form:

$$K_T = K_{20}\,\theta^{T-20} \qquad (2)$$

where:
T = temperature °C
K_{20} = decay rate at 20°C
K_T = decay rate at T°C
θ = correction coefficient

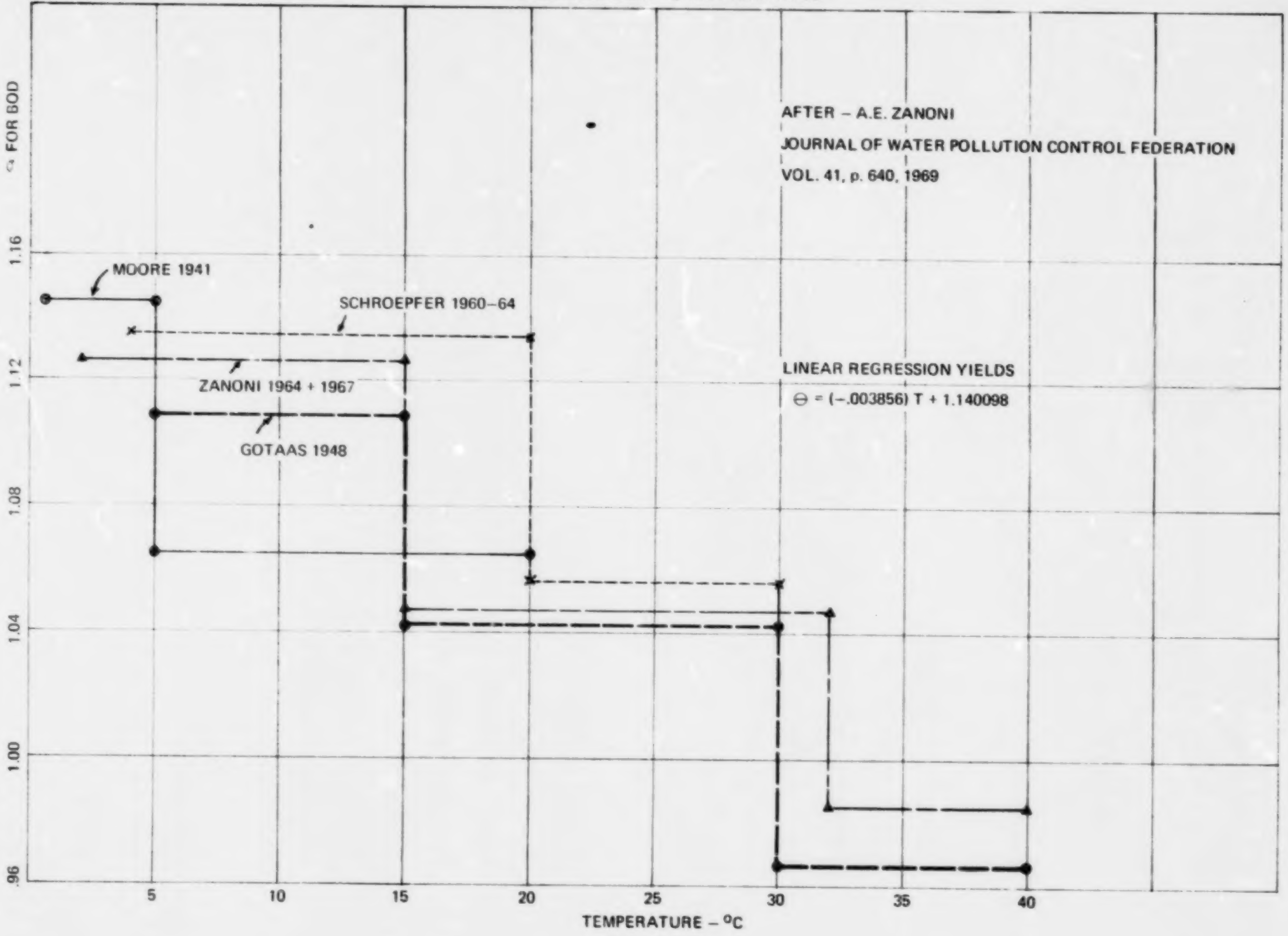
Most water quality models are run for temperature ranges of 15°C to 25°C. For this range θ is usually assumed to be a constant (about 1.047 for BOD). Very little work has been done for temperatures below 10°C and even less for temperatures below 4°C. Zanoni (1969) did some work on temperature effects on laboratory BOD decay rates. He presented his work along with a collection of various other research efforts along this line. Using the data presented by Zanoni the author developed a plot of θ versus T for laboratory BOD rates. This plot is shown in Figure IV-20. As can be seen, the data generally lies along a straight line with a negative slope. A linear regression on this data yield the equation:

$$\theta = (-0.003856)T + 1.140098 \qquad (3)$$

This equation was used in GBQUAL to adjust the BOD decay rates. There is very little data available with which to verify equation IV-2. However, a sample taken from the Petenwell Flowage on the Wisconsin River in 1971 was located. This sample is significant for two reasons. First, the Petenwell Flowage receives large amounts of paper mill wastes from several sulfite and kraft pulp and paper mills located within 15 miles upstream. This is similar to the Fox River-Green Bay area. Secondly, the particular sample was split and incubated at two temperatures. The incubation took place at 20°C and at 4°C and lasted a total of 150 days. To verify the temperature equation IV-2, the 20°C curve was first fit with a three term BOD equation. With a close fit obtained for the 20°C curve, the decay rates

FIGURE IV – 20

TEMPERATURE VS Θ FOR BOD RATES



were adjusted by equation IV-2. The 4°C curve was predicted and compared to the 4°C curve actually measured. The results of this procedure are shown in Figure IV-21. The closeness of the fit between the observed and predicted 4°C curve is particularly gratifying and lends support to the use of equation IV-3.

A complete list of all parameters used in GBQUAL appears in Table D-3.

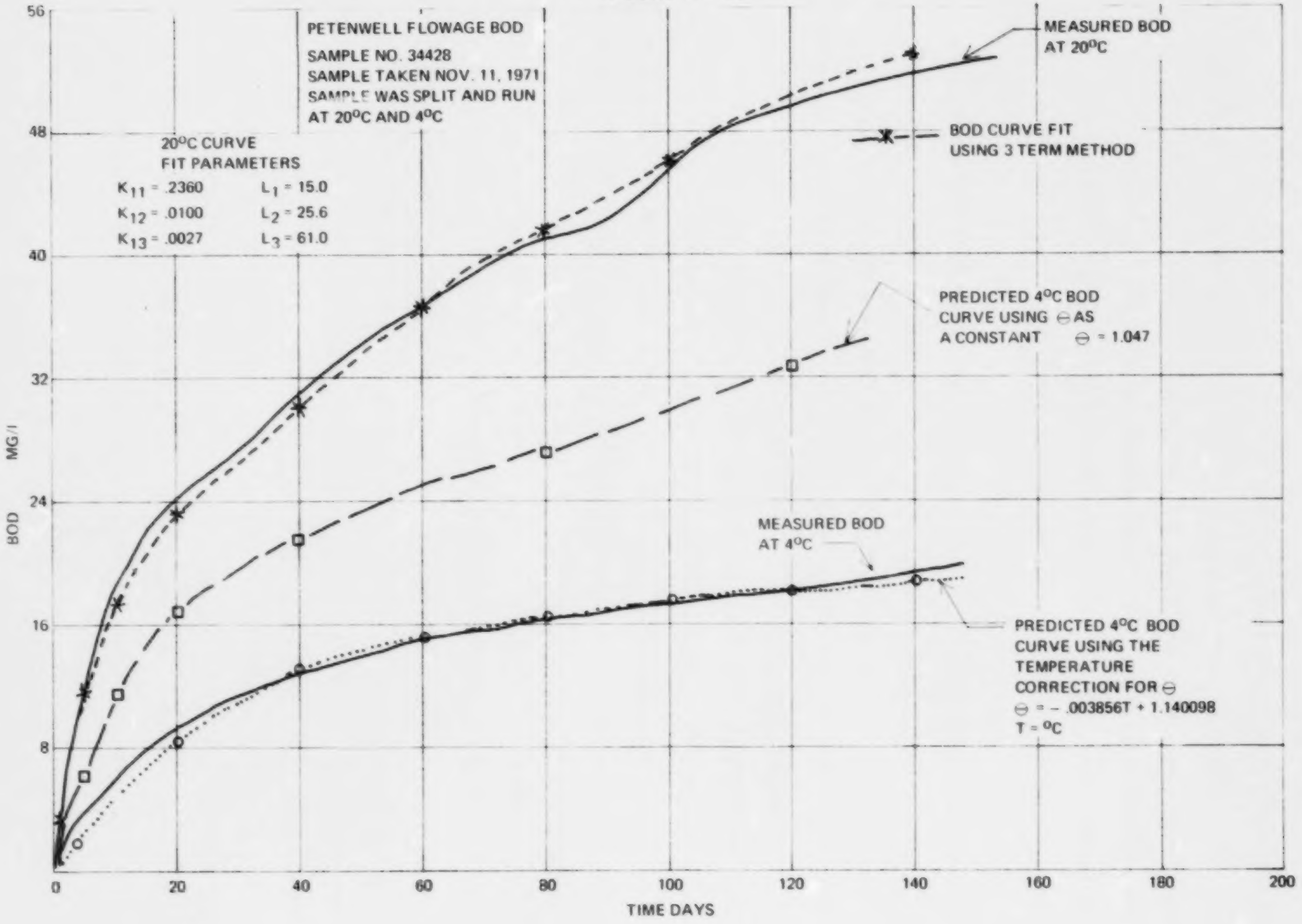
Winter Verifications

GBQUAL was verified for two sets of data obtained during the winters of 1967 and 1974. The data for 1967 consists mainly of dissolved oxygen measurements taken for scattered transects. Although the data is not complete for a good modelling attempt, valuable information can be obtained by simulating this case. Average Lower Fox River inflow for this simulation period was 3381.0 CFS.

During the winter of 1974, a survey of Green Bay was designed and carried out to gather sufficient data to attempt a proper verification of GBQUAL for ice cover conditions. This survey, as described in Section III, obtained samples over an extensive area of the Bay that was accessible. Samples for dissolved oxygen were of primary importance. Measurements of BOD_5, ammonia, nitrate and phosphorous were also obtained as were various other constituents. All these samples were taken in a five-day period in mid-February and served as the data base for the 1974 verification.

Both verification runs were executed in the same manner. This consisted of first developing the hydrodynamic scheme for the given flow rate. Next, the set of inflowing water quality conditions was chosen to represent the average water

FIGURE IV – 21


PETENWELL FLOWAGE BOD
SAMPLE NO. 34428
SAMPLE TAKEN NOV. 11, 1971
SAMPLE WAS SPLIT AND RUN AT 20°C AND 4°C
20°C CURVE FIT PARAMETERS
K_{11} = .2360
L_1 = 15.0
K_{12} = .0100
L_2 = 25.6
K_{13} = .0027
L_3 = 61.0
MEASURED BOD AT 20°C
BOD CURVE FIT USING 3 TERM METHOD
PREDICTED 4°C BOD CURVE USING θ AS A CONSTANT θ = 1.047
MEASURED BOD AT 4°C
PREDICTED 4°C BOD CURVE USING THE TEMPERATURE CORRECTION FOR θ
θ = – .003856T + 1.140098
T = °C
BOD MG/l
56
48
40
32
24
16
8
0
20
40
60
80
100
120
140
160
180
200
TIME DAYS

quality condition of the Fox River mouth over the simulation period (Jan. 1 to Mar. 15). GBQUAL was then executed for a 50 day initializing period to develop the system status which was stored and used as initial conditions to the ice cover verification runs. The initializing run assumed low temperature (2°C) and no ice cover. At this point GBQUAL was run for a 70 day simulation with the ice cover condition imposed. Prints were obtained at 20 day intervals.

The inflowing water quality for each simulation was determined from measurements of monthly monitoring data in Green Bay for the appropriate period. Table IV-7 lists data observations for the winter months of 1967 and 1974. Also listed are the values of various constituents used for the inflow in the model for each verification run. The three BOD terms in the model (which represent ultimates) were determined by evaluating the point source discharges of BOD_5 during each simulation period. Figure IV-19 represents the long term BOD curve for a specific set of BOD loadings and river flow. From this curve, the discharged BOD_5 and river flow, the appropriate concentration for the three BOD terms was calculated for each case.

The 1967 simulation results are shown in Figures IV-22 and IV-24. Plots have been drawn for dissolved oxygen and ammonia concentration. Survey data for dissolved oxygen appears in Figure IV-24. Only dissolved oxygen data is available for comparison with the 1967 survey. The simulation run indicates a rapid DO depletion over a large area just north and east of Point Sable. The area of depletion reaches values of 2 mg/l in only 20 days after the ice cover and 0 mg/l in 40 days. By day 60 of the simulation, DO depletion to 0 mg/l is indicated along the eastern bank of the inner bay and along the eastern 1/2 of the Bay up to the Dykesville area. Gradients of DO near the area are rather sharp. Ammonia concentrations

TABLE IV-7

Green Bay Measured Inflow Concentrations

	De Pere Dam (Mile 7.2)		Mason St. Bridge (Mile 1.3)		
Analysis	2/1/67	2/28/67	1/24/74	2/20/74	3/14/74
BOD_5	5.4	5.4	4.9	9.0	4.1
DO	10.6	10.7	11.0	5.8	11.2
Organic N	.91	—	1.03	.77	.84
NH_3-N	.14	—	.20	.43	.07
NO_3-N	.20	—	.19	.11	.18
TOT-P	.14	—	.11	.07	.07
Temp. °C	.5	5.0	1.0	2.0	3.0
FLOW CFS	3330.	4590.	2920.	5230.	6105.

Inflow Concentrations Used for the Simulation Runs

Constituent	1967	1974
BOD ultimate (1)	15.0	5.0
BOD ultimate (2)	20.0	20.0
BOD ultimate (3)	50.0	50.0
DO	10.0	10.0
Organic N	.9	.75
NH_3-N	.5	.5
NO_3-N	.2	.15
SOL-P	.03	.03
Temp °C	2.0	2.0
FLOW	3381.5	4852.8

FIGURE IV-22

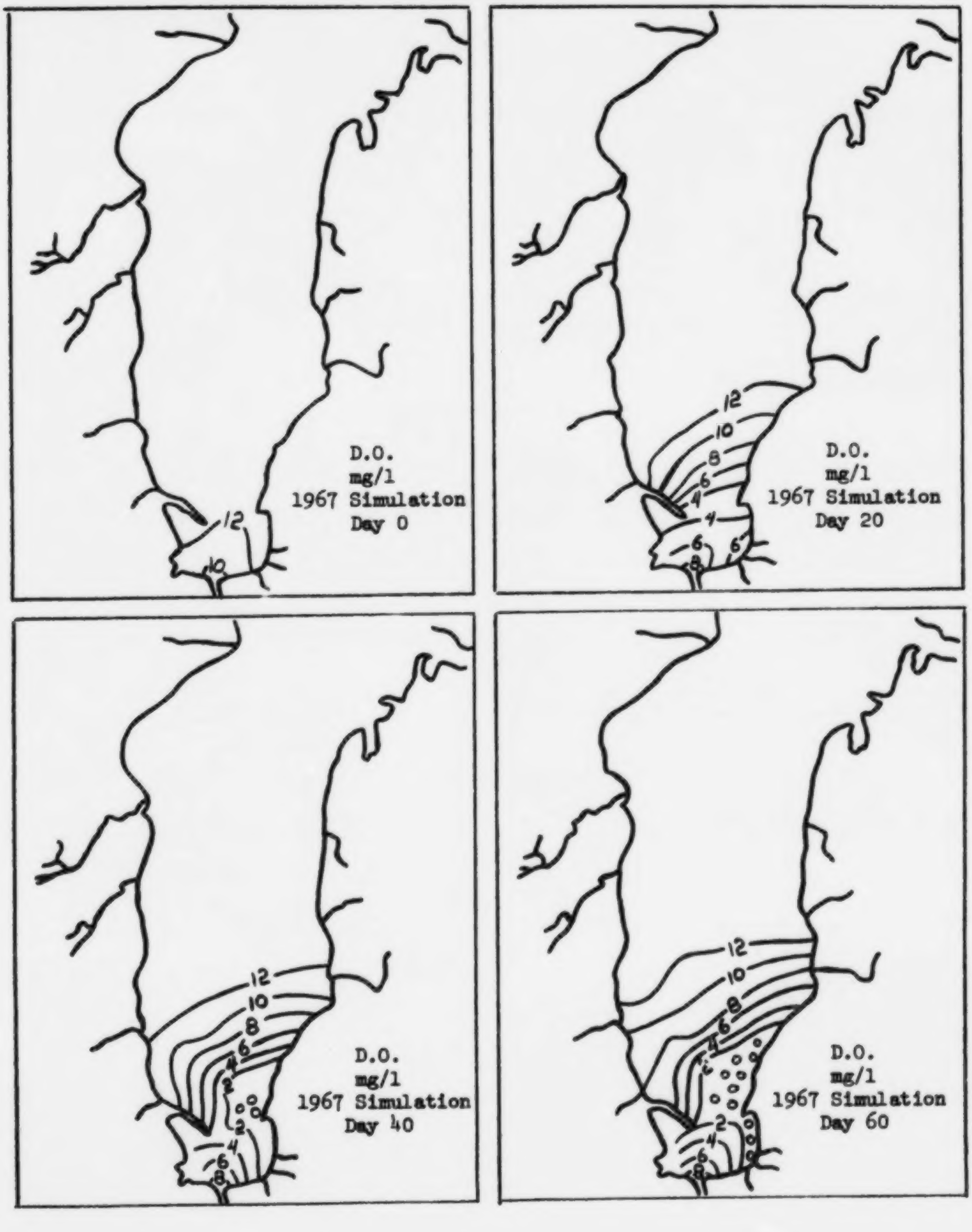

D.O.
mg/l
1967 Simulation
Day 0
12
10
D.O.
mg/l
1967 Simulation
Day 20
12
10
8
6
4
4
6
6
8
D.O.
mg/l
1967 Simulation
Day 40
12
10
8
6
4
2
2
4
6
8
D.O.
mg/l
1967 Simulation
Day 60
12
10
8
6
4
2
4
6
8

FIGURE IV-23

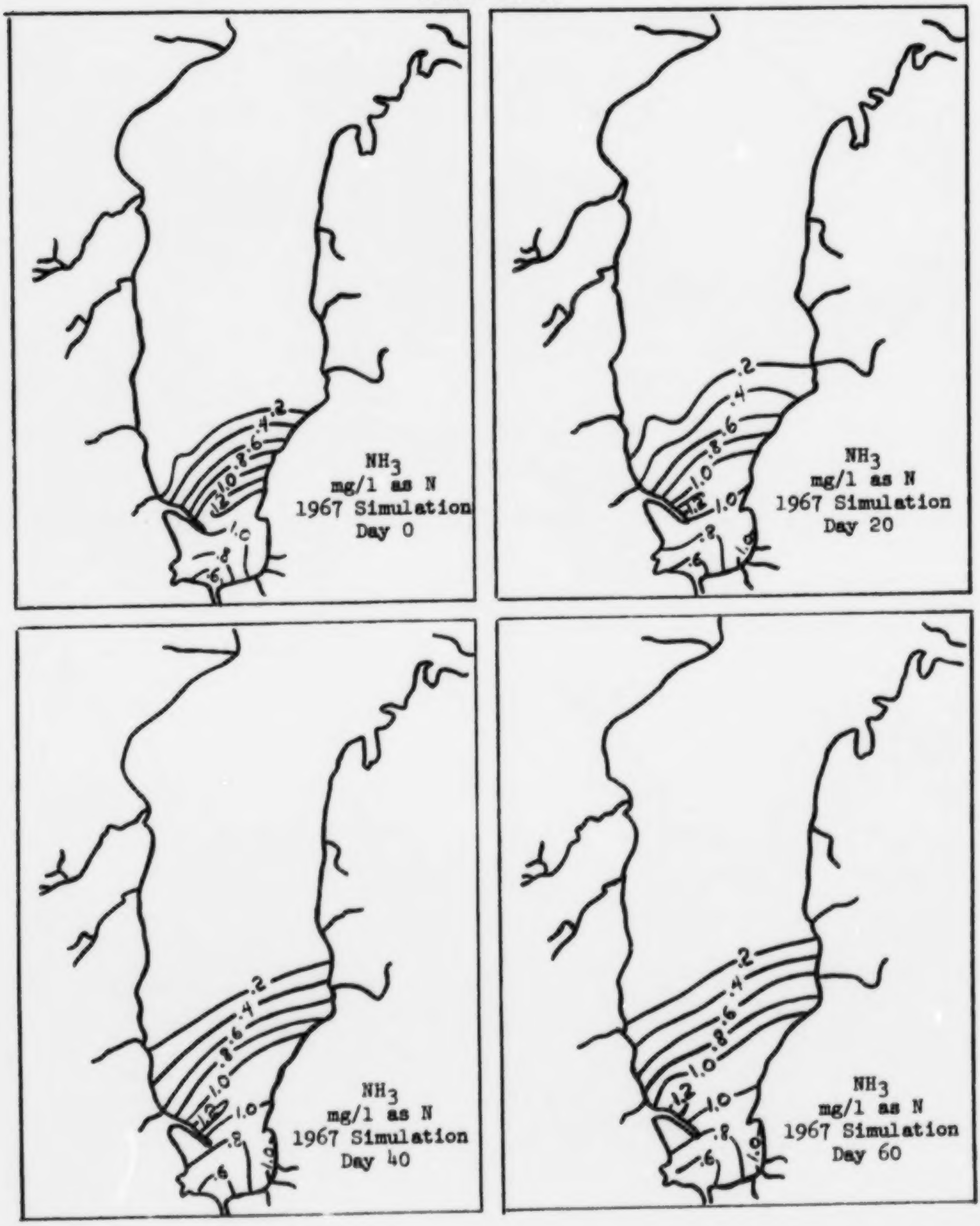

.2
.4
.6
.8
1.0
1.2
1.0
.8
.6
NH_3
mg/l as N
1967 Simulation
Day 0
.2
.4
.6
.8
1.0
1.2
1.0
.8
.6
1.0
NH_3
mg/l as N
1967 Simulation
Day 20
.2
.4
.6
.8
1.0
1.2
1.0
.8
.6
1.0
NH_3
mg/l as N
1967 Simulation
Day 40
.2
.4
.6
.8
1.0
1.2
1.0
.8
.6
1.0
NH_3
mg/l as N
1967 Simulation
Day 60

FIGURE IV-24

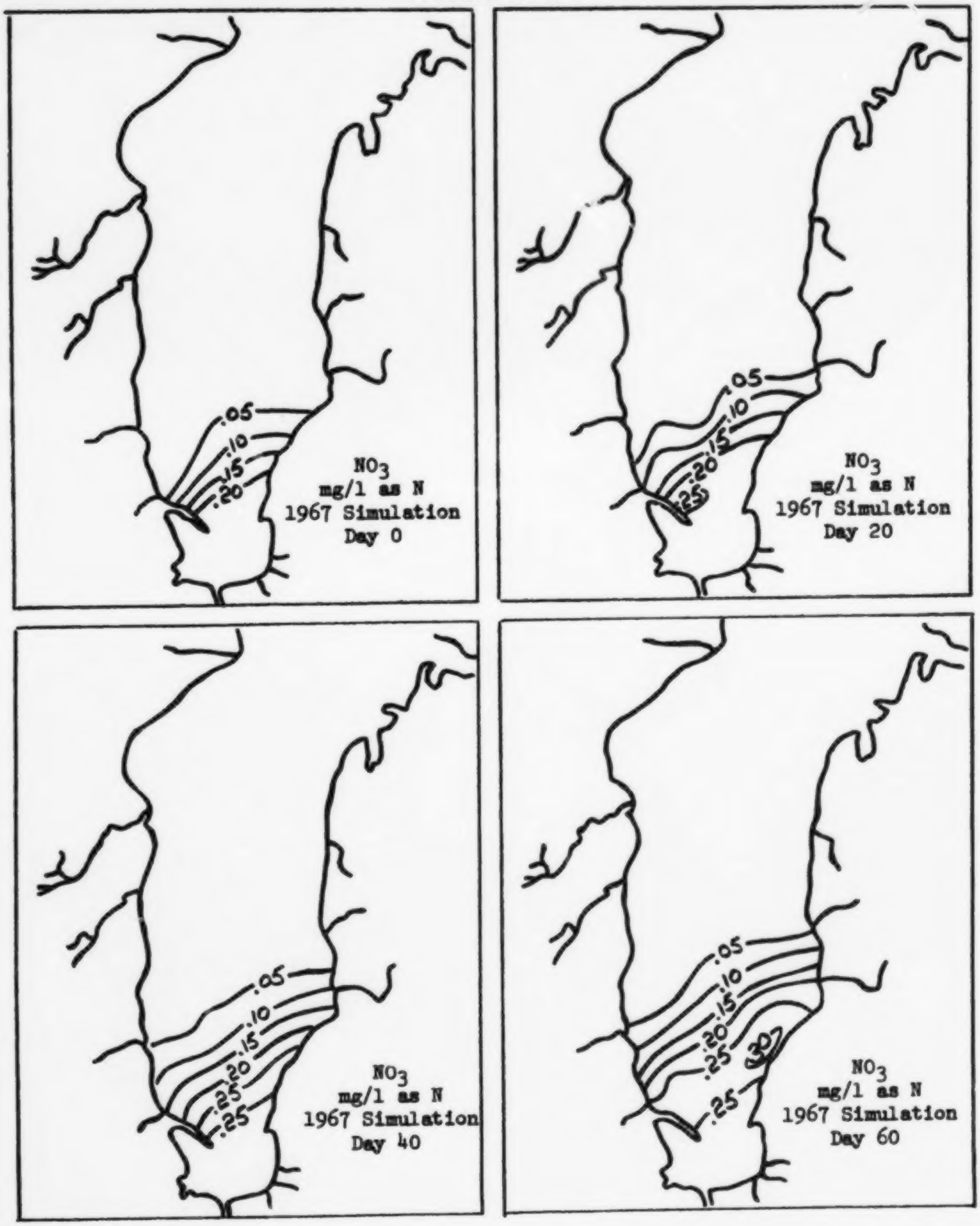
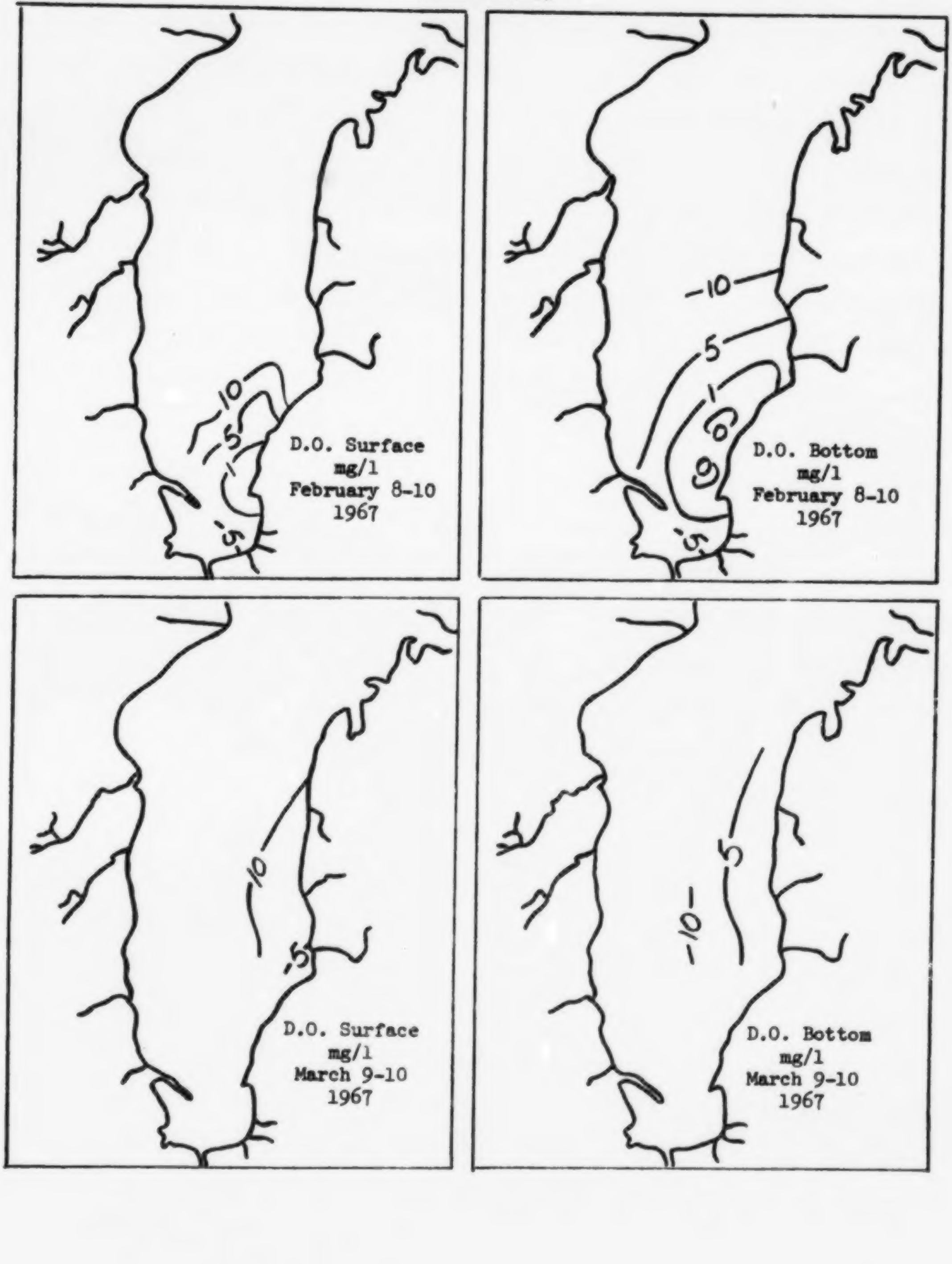

.05
.10
.15
.20
NO_3
mg/l as N
1967 Simulation
Day 0
.05
.10
.15
.20
.25
NO_3
mg/l as N
1967 Simulation
Day 20
.05
.10
.15
.20
.25
.25
NO_3
mg/l as N
1967 Simulation
Day 40
.05
.10
.15
.20
.25
.30
.25
NO_3
mg/l as N
1967 Simulation
Day 60

FIGURE IV-25



D.O. Surface
mg/l
February 8-10
1967

D.O. Bottom
mg/l
February 8-10
1967

D.O. Surface
mg/l
March 9-10
1967

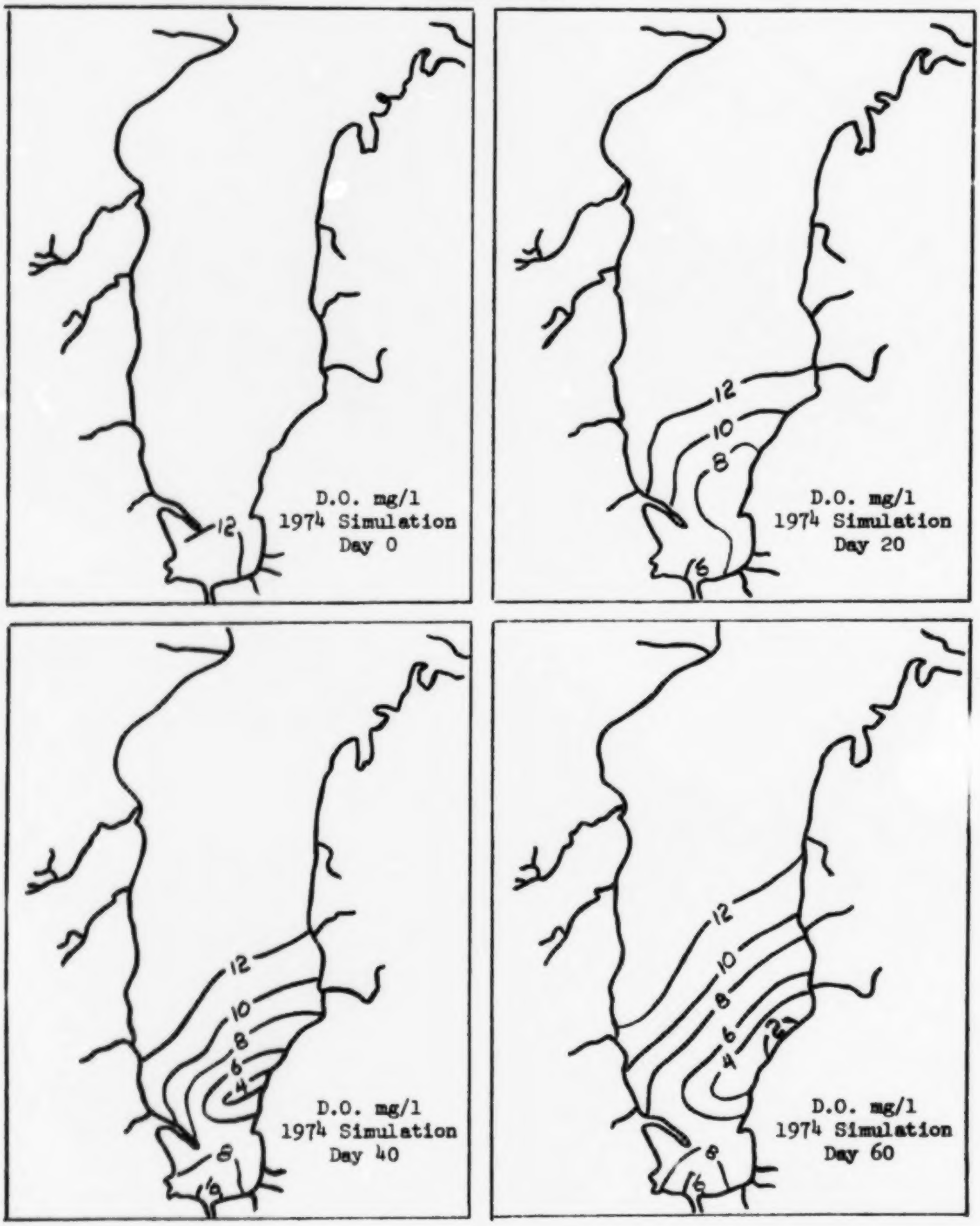
D.O. Bottom
mg/l
March 9-10
1967

10
5
1
5
10
5
1
.5
.1
.5
10
5
10
5

after 60 days of simulation show concentrations of 1 mg/l over approximately the same area that had zero DO. A decreasing concentration gradient occurs in all directions around this area. The gradients are not nearly as sharp as those for the DO. Dissolved oxygen was measured in Green Bay on February 8-10, 1967 and March 9-10, 1967. The February survey would correspond to approximately 40 days of ice cover. Direct comparison of this data is possible with day 40 of the simulation run. The model showed a rather linear gradient of DO from the Fox River mouth to Point Sable. The DO went from 8.0 mg/l to .5 mg/l. The measured DO showed levels of 5 and 6 mg/l in the Bay Beach area and .5 to .1 mg/l near Point Sable. Beyond Point Sable, a large area near Red Banks showed 0.0 mg/l DO from the top to the bottom. Low DO's near the bottom generally covered a larger area than those measured near the surface. Measurements during the March survey only covered areas north of Dykesville. Low DO's were seen in all areas but only very close to the bottom. Near the surface and at mid depths the DO's were nearly always above 8.0 mg/l. This survey would correspond to about 70 days after the ice cover began. The closest simulation printout is for day 60. This printout reveals a pattern similar to the 40 day printout but with slightly expanded extent. DO levels above Dykesville generally are above 8.0 mg/l. The Dykesville area is right in the vicinity of the positive DO gradient. In general the match for the 1967 DO pattern is quite acceptable.

The 1974 verification is much more complete. The data includes measurements of NH_3-N, NO_3-N, organic N, total and soluable phosphate as well as dissolved oxygen and BOD_5. The data for the February 18-20, 1974 survey is presented in Section III. The simulation output for various constituents is shown in Figures IV-26 through IV-29. Ice cover on Green Bay during 1974 began about January 10th (private communication, Wiersma 1974). Therefore the February 18-20, 1974 survey

FIGURE IV-26



D.O. mg/l
1974 Simulation
Day 0

D.O. mg/l
1974 Simulation
Day 20

D.O. mg/l
1974 Simulation
Day 40

D.O. mg/l
1974 Simulation
Day 60

12
12
10
8
6
8
12
10
8
6
4
8
6
12
10
8
6
4
2
8
6

FIGURE IV-27

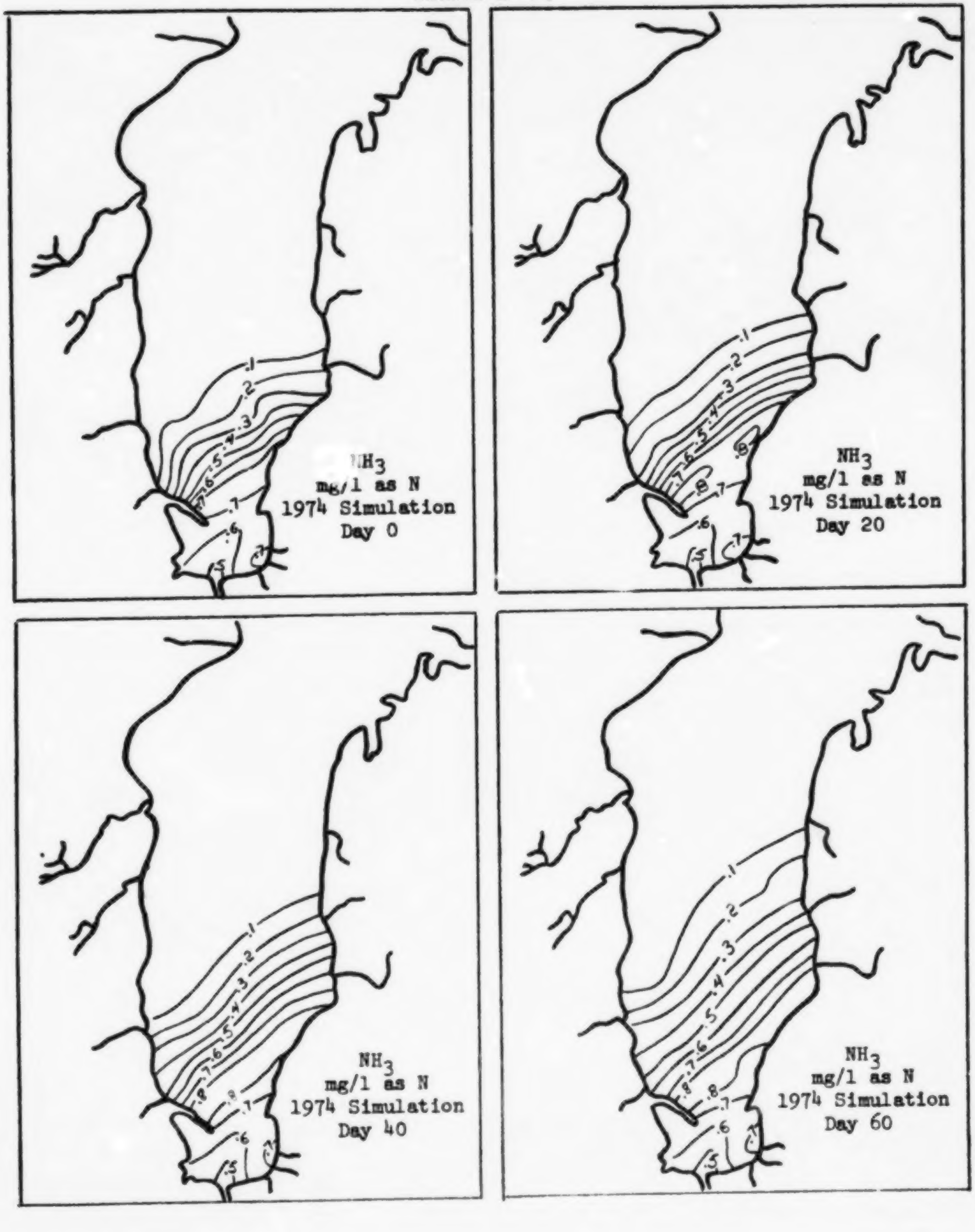

NH$_3$
mg/l as N
1974 Simulation
Day 0
NH$_3$
mg/l as N
1974 Simulation
Day 20
NH$_3$
mg/l as N
1974 Simulation
Day 40
NH$_3$
mg/l as N
1974 Simulation
Day 60

FIGURE IV-28

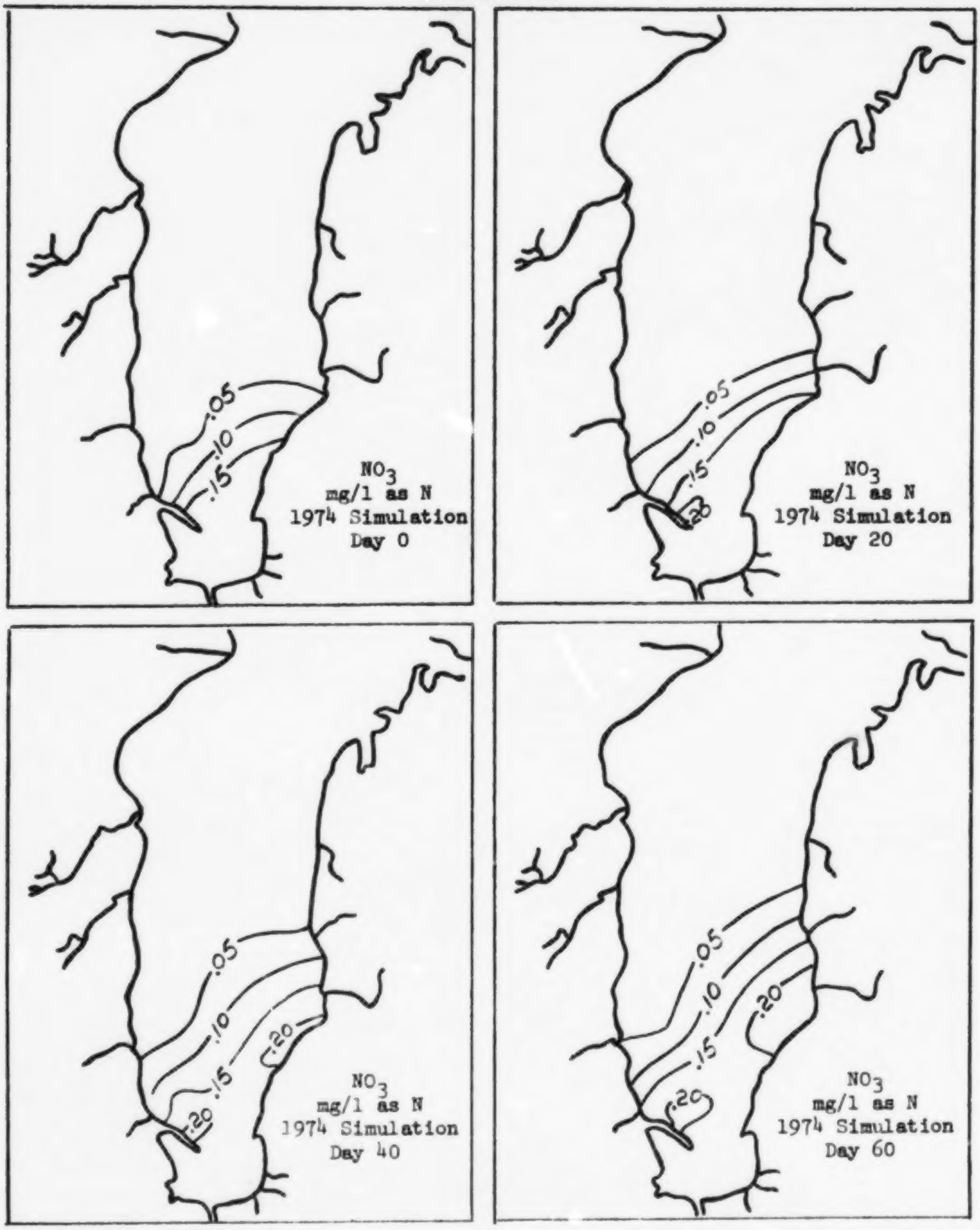
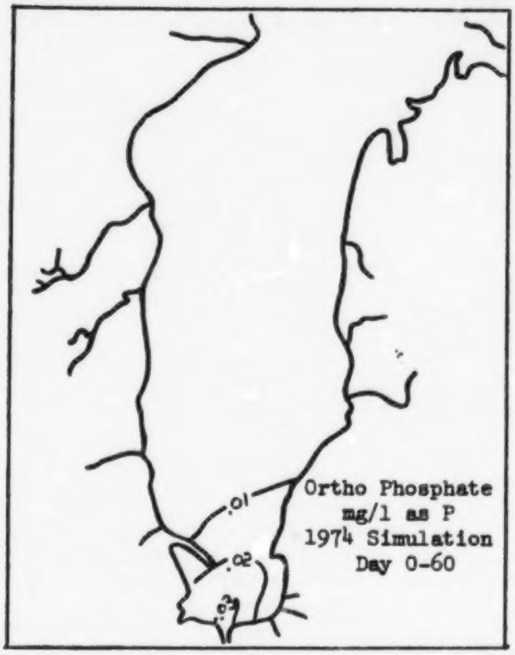
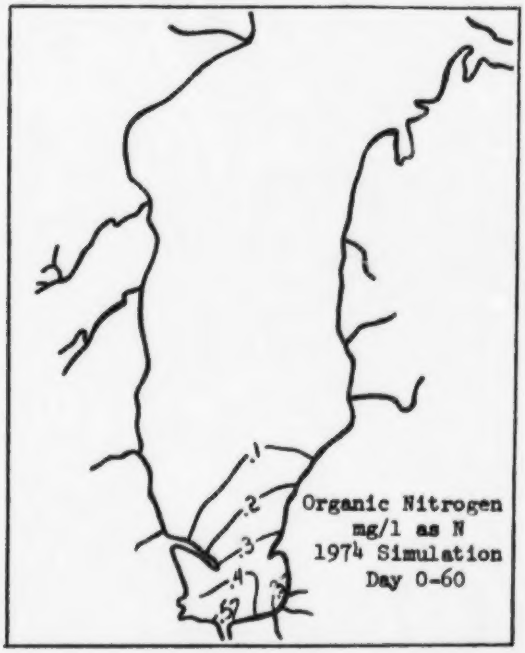

.05
.10
.15
NO_3
mg/1 as N
1974 Simulation
Day 0
.05
.10
.15
.20
NO_3
mg/1 as N
1974 Simulation
Day 20
.05
.10
.15
.20
.20
NO_3
mg/1 as N
1974 Simulation
Day 40
.05
.10
.15
.20
.20
NO_3
mg/1 as N
1974 Simulation
Day 60

FIGURE IV-29



Ortho Phosphate
mg/l as P
1974 Simulation
Day 0-60



Organic Nitrogen
mg/l as N
1974 Simulation
Day 0-60

would correspond to about day 40 of the ice cover simulation. The 40 day printout shows a 5.0 mg/l contour covering an oblong area off Red Banks. This corresponds very well with the measured values in this area shown in Section III. Values around 3.0 mg/l DO are indicated in the data in the Red Banks area. This corresponds nicely with the simulation output.

The ammonia profiles from the simulation output at day 40 appear to be slightly high when compared to the measured data. The model shows a wide area, from the center of the bay below Long Tail and Point Sable extending beyond Dykesville across to the Big Suamico River, that is above 0.6 mg/l ammonia. Inside this area levels are calculated as high as .85 mg/l. The survey data shows a long triangular area centered around Point Sable and extending to Red Banks that has 0.6 mg/l ammonia. The higher level in the model may well be a result of over estimating the inflowing concentration of NH_3-N in the simulation run. Measured values at the Mason St. Bridge (shown in Table IV-7) indicate the inflow concentration should have been .3 to .4 mg/l ammonia instead of the .5 mg/l value. It is worth noting, however, that the shape of the .6 mg/l area in the simulation output is roughly correct and is centered over the same area.

Winter Prediction Runs

Two Green Bay winter prediction runs were made with the model. Both of these runs utilized all decay coefficients the same as for the verification runs. The only variable was the flow and concentration of BOD (high flow will of course dilute the discharged BOD). Table IV-8 lists the inflow conditions used for these two runs.

TABLE IV-8

Green Bay Simulation Inflow Concentrations

	Run 1	Run 2
BOD-1	2.0	5.0
BOD-2	4.0	10.0
BOD-3	30.0	50.0
DO	10.0	8.0
Organic N	0.5	0.6
NH_3-N	0.5	0.5
NO_3-N	0.2	0.2
Sol-P	0.03	0.03
Temp °C	2.0	2.0
FLOW CFS	2400.	912.

Critical flow conditions for the winter case were determined by scanning the last 15 years of records. The lowest flow (averaged over January, February and March) for the winter period was found to be 2400 CFS. This flow was used along with the flow of 912 CFS, the 7 day, 10 year low flow. The results of both of these runs are shown in Figures IV-30 to IV-37. The flow case for 912 CFS was run for comparison purposes only. A flow this low over the entire winter period is unrealistically low. The 2400 CFS flow case more accurately represents the "worst case" condition for the winter months.

The 2400 CFS run shows that after 60 days of ice cover the minimum dissolved oxygen level drops to 6.1 mg/l. The main difficulty in accepting this result lies in our estimation of the ultimate BOD used for the inflowing concentration at the mouth of the Fox River. Figure IV-38 illustrates two 50 day BOD curves. The top curve is the same BOD curve shown in Figure IV-19 and is described by the given 3 term equation. The bottom curve was selected as representative of the ultimate BOD curve under BPT treatment conditions and 2400 CFS. It was assumed that the largest percent reduction would be from the most easily oxidizable substances. Thus L_1 was reduced by 87.5%, L_2 by 75% and L_3 by only 40%. Our results show that under the given ultimate BOD inflow, 5 mg/l of dissolved oxygen will probably be met for average winter flows as low as 2400 CFS. However, the sag in DO comes so close to 5.0 mg/l that we must conclude that the given BOD ultimate curve represents the maximum allowable BOD to maintain 5.0 mg/l at all times under ice conditions. If our assumption concerning the ultimate BOD curve for BPT underestimates the actual BOD loading, then water quality violations of the dissolved oxygen can be expected to continue. In the Green Bay area, (De Pere to Green Bay), BPT will represent about a 75% reduction in 5 day BOD loading based on present permits. The curves shown in Figure IV-38 show a 74% reduction at the 5th day. It therefore appears that our estimation is close to the expected BPT conditions.

FIGURE IV-30

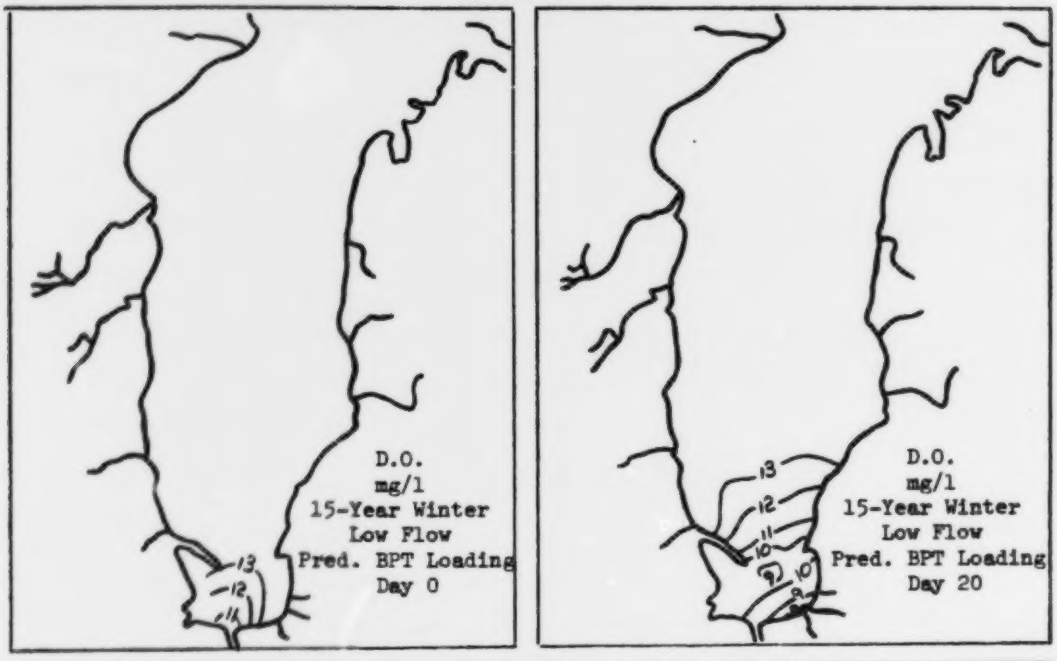

D.O.
mg/1
15-Year Winter
Low Flow
Pred. BPT Loading
Day 0
13
12
11
D.O.
mg/1
15-Year Winter
Low Flow
Pred. BPT Loading
Day 20
13
12
11
10
9
10
9
D.O.
mg/1
15-Year Winter
Low Flow
Pred. BPT Loading
Day 40
13
12
11
10
9
8
9
10
8
D.O.
mg/1
15-Year Winter
Low Flow
Pred. BPT Loading
Day 60
13
12
11
10
9
8
7
6
8
9
10
7

FIGURE IV-31

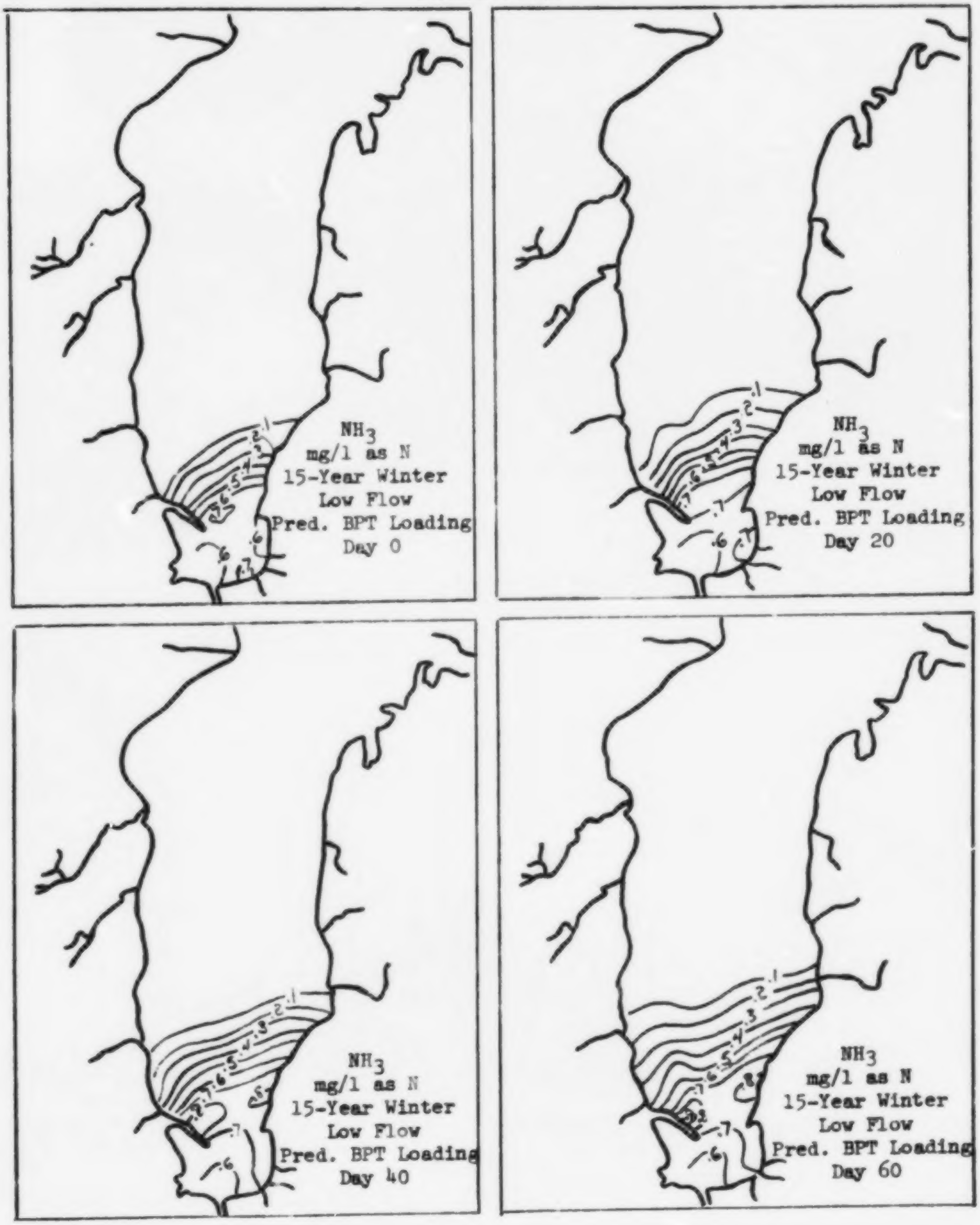

NH_3
mg/l as N
15-Year Winter
Low Flow
Pred. BPT Loading
Day 0
NH_3
mg/l as N
15-Year Winter
Low Flow
Pred. BPT Loading
Day 20
NH_3
mg/l as N
15-Year Winter
Low Flow
Pred. BPT Loading
Day 40
NH_3
mg/l as N
15-Year Winter
Low Flow
Pred. BPT Loading
Day 60
.1
.2
.3
.4
.5
.6
.7
.8

FIGURE IV-32

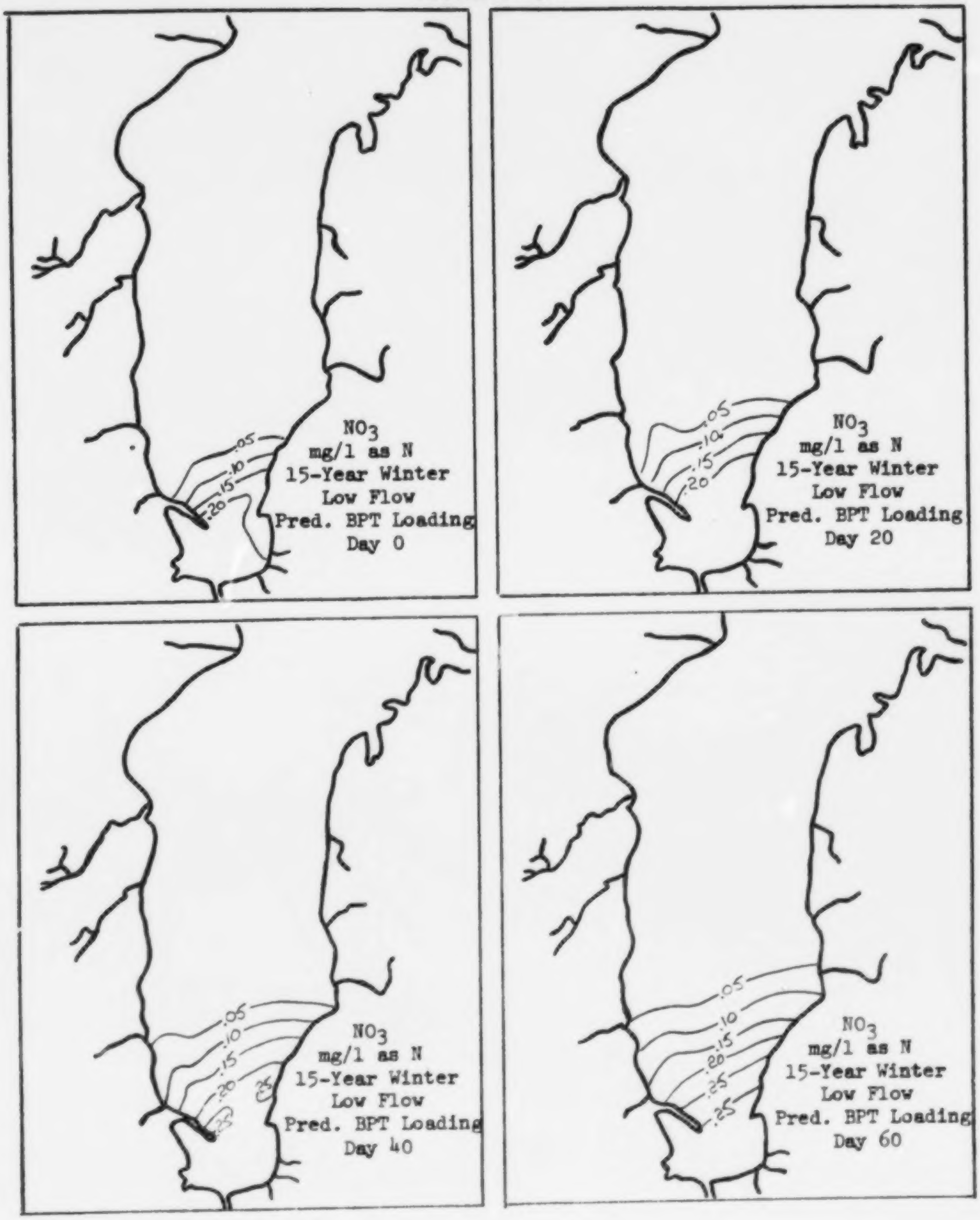
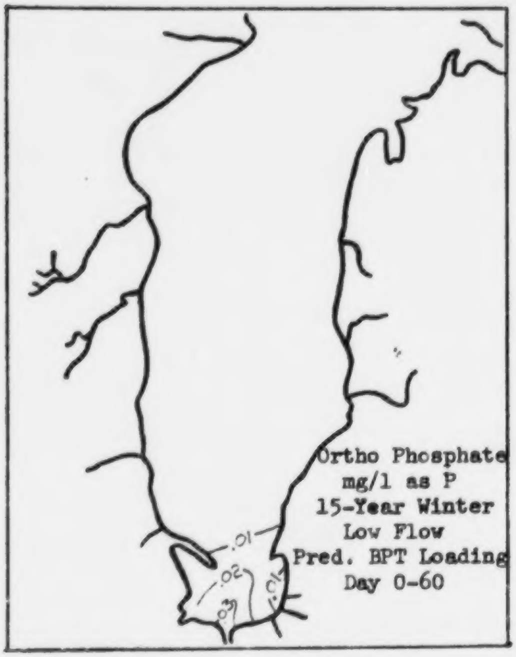

.05
.10
.15
.20
NO_3
mg/l as N
15-Year Winter
Low Flow
Pred. BPT Loading
Day 0
.05
.10
.15
.20
NO_3
mg/l as N
15-Year Winter
Low Flow
Pred. BPT Loading
Day 20
.05
.10
.15
.20
.25
.25
NO_3
mg/l as N
15-Year Winter
Low Flow
Pred. BPT Loading
Day 40
.05
.10
.15
.20
.25
.25
NO_3
mg/l as N
15-Year Winter
Low Flow
Pred. BPT Loading
Day 60

FIGURE IV-33


Ortho Phosphate
mg/l as P
15-Year Winter
Low Flow
Pred. BPT Loading
Day 0-60
.01
.02
.03
.01

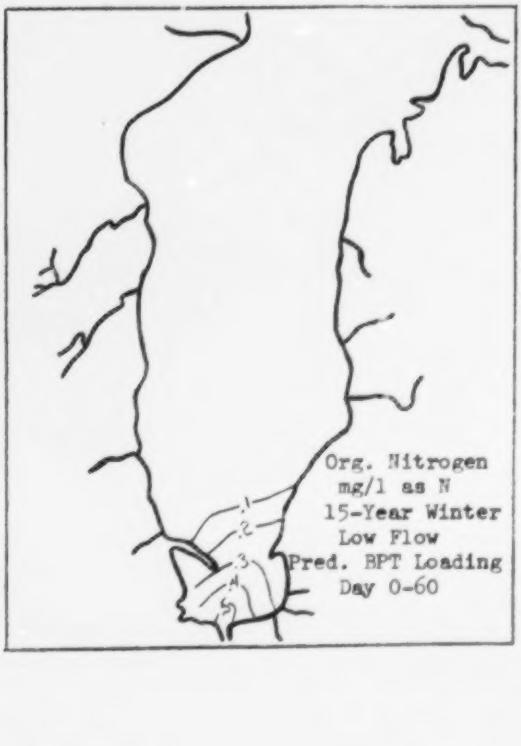

Org. Nitrogen
mg/l as N
15-Year Winter
Low Flow
Pred. BPT Loading
Day 0-60
.1
.2
.3
.4
.5

FIGURE IV-34

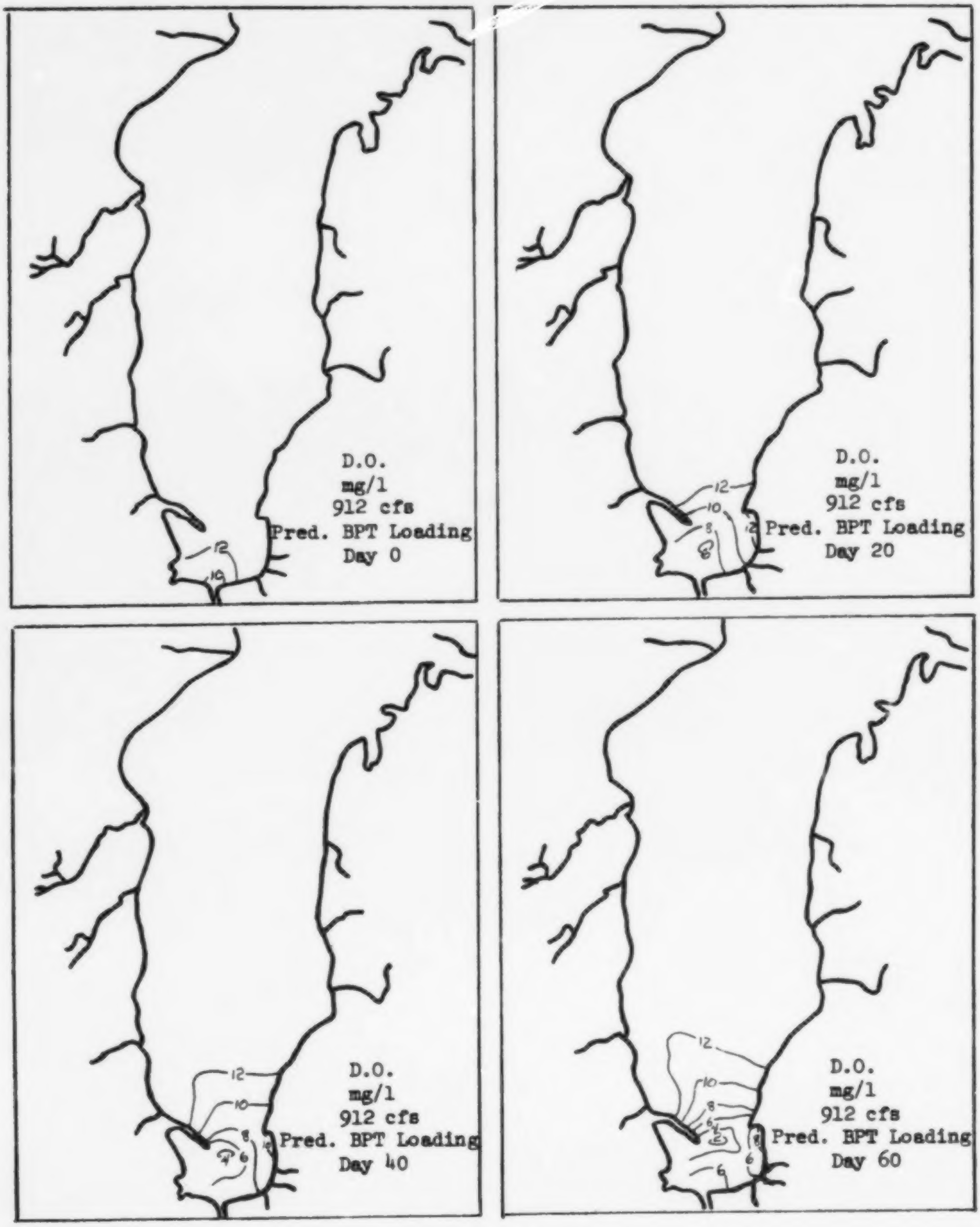

D.O.
mg/1
912 cfs
Pred. BPT Loading
Day 0
12
10
D.O.
mg/1
912 cfs
Pred. BPT Loading
Day 20
12
10
8
8
12
D.O.
mg/1
912 cfs
Pred. BPT Loading
Day 40
12
10
8
6
4
4
D.O.
mg/1
912 cfs
Pred. BPT Loading
Day 60
12
10
8
6
4
6
6
8

FIGURE IV-35

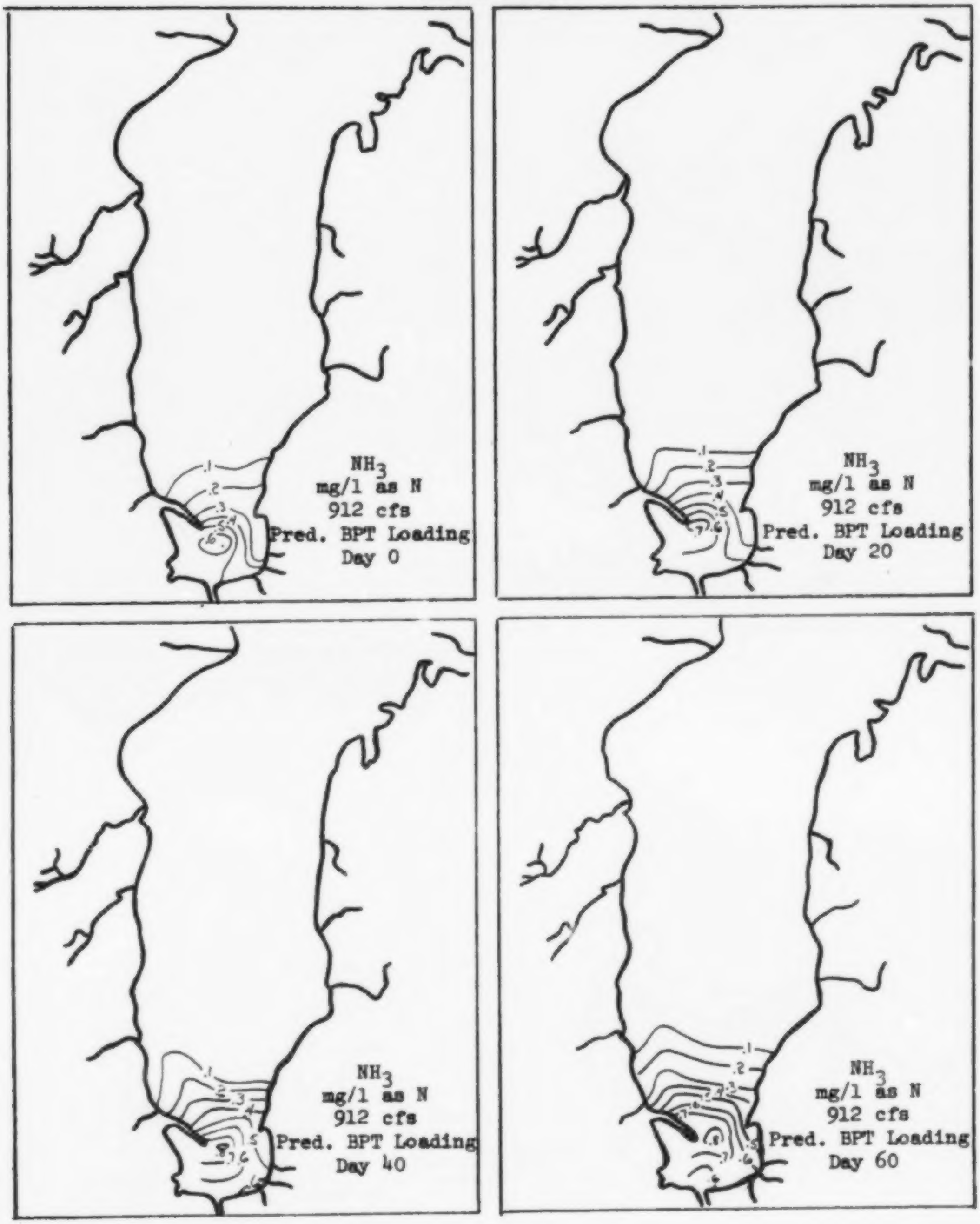

NH3
mg/l as N
912 cfs
Pred. BPT Loading
Day 0
NH3
mg/l as N
912 cfs
Pred. BPT Loading
Day 20
NH3
mg/l as N
912 cfs
Pred. BPT Loading
Day 40
NH3
mg/l as N
912 cfs
Pred. BPT Loading
Day 60

FIGURE IV-36

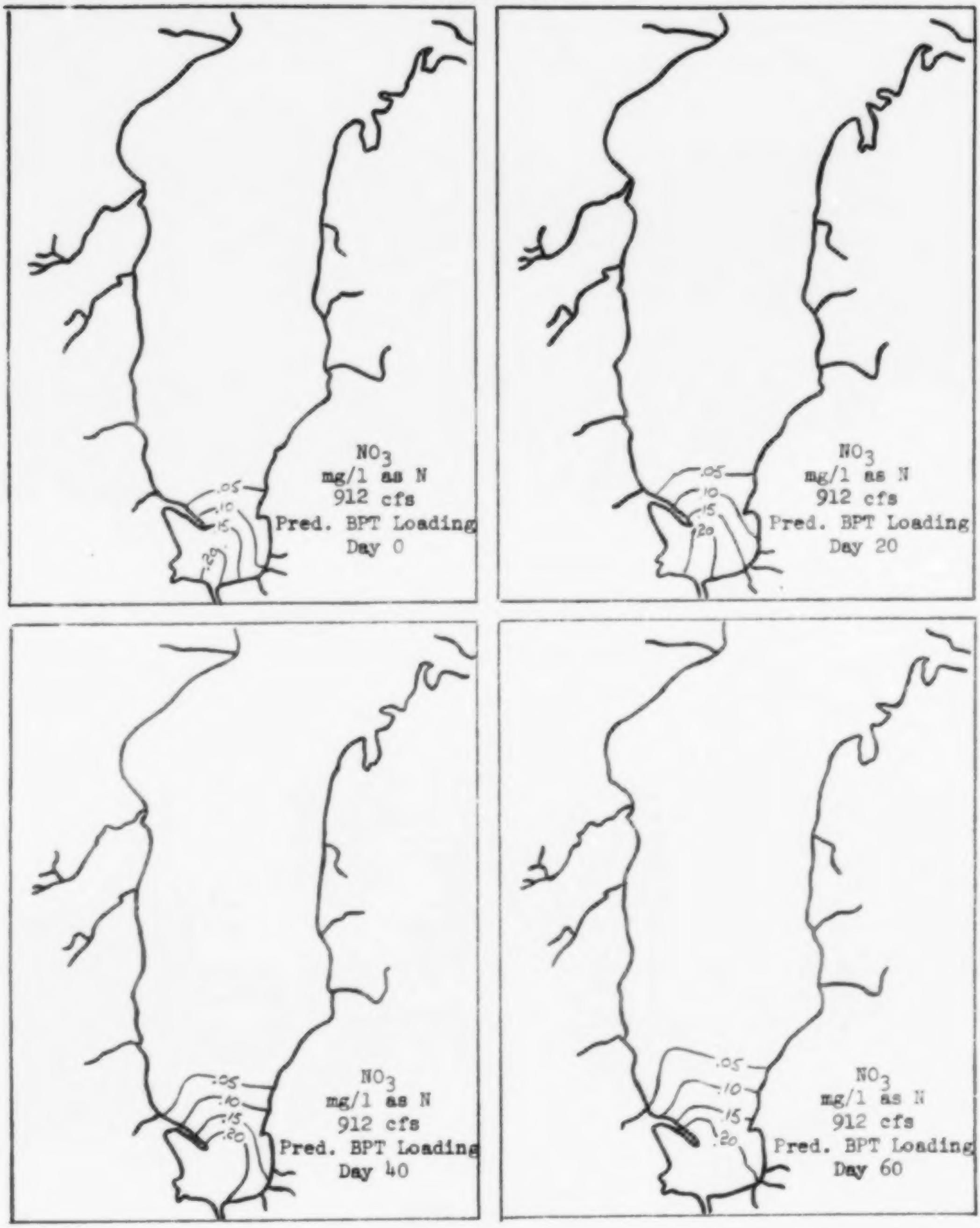
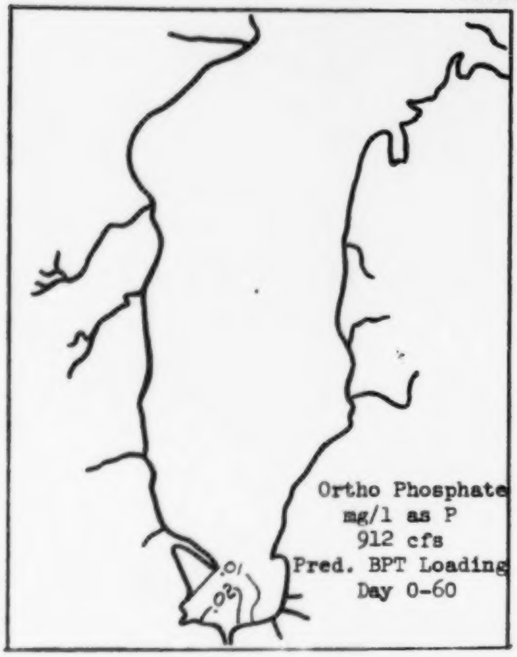
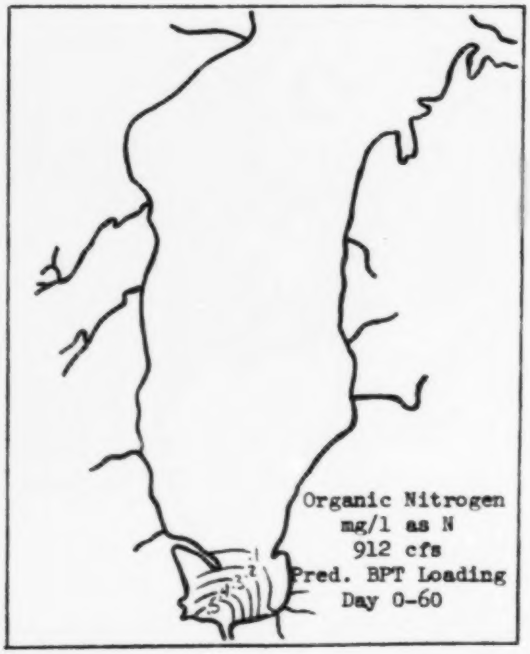

.05
.10
.15
.20
NO_3
mg/1 as N
912 cfs
Pred. BPT Loading
Day 0
.05
.10
.15
.20
NO_3
mg/1 as N
912 cfs
Pred. BPT Loading
Day 20
.05
.10
.15
.20
NO_3
mg/1 as N
912 cfs
Pred. BPT Loading
Day 40
.05
.10
.15
.20
NO_3
mg/1 as N
912 cfs
Pred. BPT Loading
Day 60

FIGURE IV-37

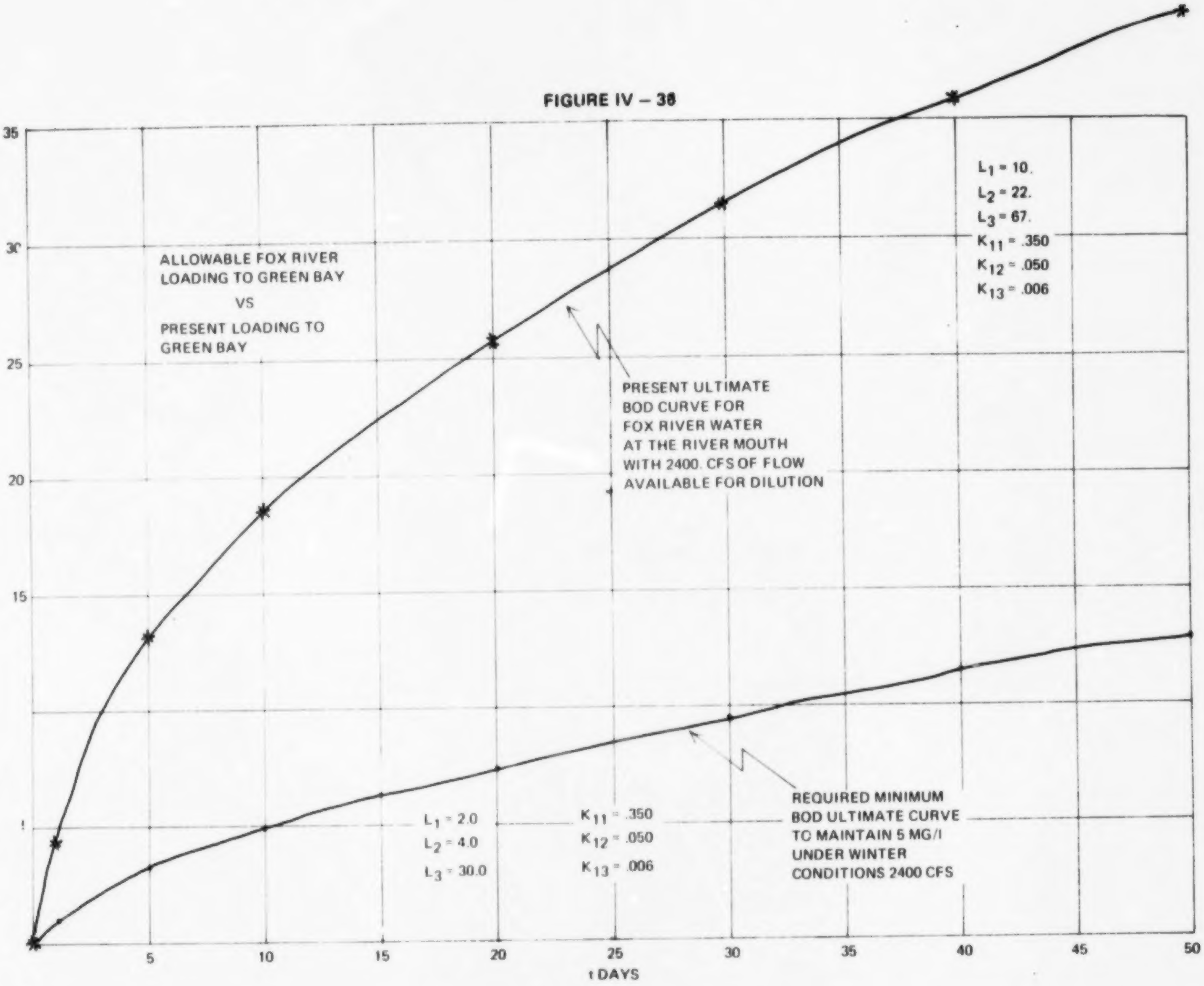


Ortho Phosphate
mg/l as P
912 cfs
Pred. BPT Loading
Day 0-60



Organic Nitrogen
mg/l as N
912 cfs
Pred. BPT Loading
Day 0-60

FIGURE IV – 38


ALLOWABLE FOX RIVER
LOADING TO GREEN BAY
VS
PRESENT LOADING TO
GREEN BAY
PRESENT ULTIMATE
BOD CURVE FOR
FOX RIVER WATER
AT THE RIVER MOUTH
WITH 2400. CFS OF FLOW
AVAILABLE FOR DILUTION
L1 = 10.
L2 = 22.
L3 = 67.
K11 = .350
K12 = .050
K13 = .006
REQUIRED MINIMUM
BOD ULTIMATE CURVE
TO MAINTAIN 5 MG/l
UNDER WINTER
CONDITIONS 2400 CFS
L1 = 2.0
L2 = 4.0
L3 = 30.0
K11 = .350
K12 = .050
K13 = .006
35
30
25
20
15
5
10
15
20
25
30
35
40
45
50
t DAYS

The final waste load allocation under critical summer flow conditions (developed earlier) shows an overall 37% reduction in the 5 day BOD loading compared to BPT loadings. Under the WLA discharge scheme it would be extremely unlikely that the dissolved oxygen would drop below 5.0 mg/l during the ice cover. On the basis of the above studies, it can be concluded that the summer critical condition in the Lower Fox River represents the "worst case condition" for the Fox River-Green Bay system. If high levels of DO can be maintained in the river by limiting the BOD discharges, the winter DO sag in the Lower Bay should be eliminated.

SECTION V

V. DISCUSSION

Dissolved Oxygen

One of the most important objectives of this project consists of determining the worst case condition for dissolved oxygen in the Lower Fox River-Green Bay system. The worst case condition acts as the controlling situation in the determination of the final "waste load allocation". For the Bay itself, the worst case appears to be the winter ice-cover period. During this time the dissolved oxygen can go to zero over wide areas of the Bay. This massive DO sag disrupts potential commercial and sport fishing in the Lower Bay. Also chemical reactions take place in this region that may enhance the eutrophic nature of Green Bay.

In the Lower Fox River, the critical condition occurs during the high temperature, low flow season. During the months of late June to early September, high temperatures and low flow can cause very low levels of dissolved oxygen over 10 to 20 miles of the Lower Fox River. Levels of DO below 1 mg/l are not uncommon. This level of dissolved oxygen virtually excludes the possibility of fish life in these stretches of the river.

An important question that must be asked at this point is which of these conditions is most critical to the overall dissolved oxygen balance? The answer to this question was not at all clear before modelling was undertaken. If we limit BOD discharges such that the winter problem for DO is corrected, have we done enough to correct the summer low DO's in the river also? Between the two modelling efforts developed for this study, the answer appears to be no. The most critical dissolved oxygen condition will occur during the summer months and will affect water in the Lower Fox River particularly in the Green Bay area. With all dischargers limited to "Best Practicable Treatment", serious oxygen problems will still be present in the Lower Fox River. Figure IV-12 diagrams the expected result for BPT discharges and the 7 day 10 year (7Q10) low flow. If we study the expected BPT effect on the ice-covered Bay for low flow conditions, we note that the DO is expected to drop no lower that about 6 mg/l (more than enough for most species of fish). We must observe however, that the winter low flow rate is nearly 3 times the statistical 7Q10 low flow. There are two reasons for this. First, since the winter sag occurs over a three month period, we must consider a 3 month average flow. Naturally, the lowest flow over a 3 month period for a river such as the Lower Fox River will be considerably greater than the 7Q10 flow. Secondly, the lowest flows never occur during the winter months. Thus the average flow during January, February and March is considerably higher than the average flow of July and August. Therefore it is not realistic to use the 7Q10 flow for the winter prediction runs. The choice of 2400 CFS was based on the lowest average flow for January through March observed in the past 15 years of record. If we assume that 2400 CFS represents a logical choice for the winter low flow and all dischargers are limited to "Best Practicable Treatment", then based on the Green Bay model, the dissolved oxygen will not go below 5 mg/l in Green Bay.

The above conclusion does not guarantee that other conditions will not interact to lower the DO below 5 mg/l during the winter months. If a particular winter has flows lower than 2400 CFS, DO problems may develop. The run made with 912 CFS as the average winter inflow generated a DO sag that went down to 2 mg/l.

Secondly, all the discharge permits allow for maximum levels of discharge that may range from 1.5 to 3 times the monthly average. If one or more large dischargers release an effluent that approaches their maximum limit then the DO may be lowered below 5 mg/l even if the flow is greater than 2400 CFS. Since there is very little margin in meeting the 5 mg/l DO level under BPT conditions it is therefore manditory that dischargers be regulated very tightly. Maximum discharges should be no greater than 1.5 times the average. Vigorous enforcement must be maintained to discourage slug load inputs that could generate a costly fish kill. Improving water quality should generate higher populations of desirable fish amplifying the importance of tight enforcement.

At present the Wisconsin Department of Natural Resources allows for a dissolved oxygen variance in Green Bay. Chapter NR 103.05 (5) states that waters "southeasterly from the navigation channel and southerly from the north line of Brown County...shall not be lowered to less than 2 mg/l at any time" during the period January 1 to April 1. In light of the conclusions presented above, Chapter NR 103.05 (5) should be reevaluated. Under the Wisconsin Pollution Discharge Elimination System (WPDES), all discharges should be meeting "Best Practicable Treatment" levels by the end of 1977. At that time it can be concluded that a dissolved oxygen standard of 5 mg/l should be applied to the area of Green Bay that is specified in Chapter NR 103.05 (5). The variance condition that now applies over that region of Green Bay will no longer be necessary except under the extreme conditions mentioned above. It is most likely that any violation of 5 mg/l that may occur will not be very serious and will surely not require a 2 mg/l variance.

The dissolved oxygen conditions in the Lower Fox River itself is another matter. Even with BPT conditions met by all dischargers, violations of the present variance conditions for dissolved oxygen may occur in at least 3 places along the river during the 7Q10 flow and high temperatures. Thus by the year 1977, one can expect water quality violations to continue in the Lower Fox River.

Table IV-6 presents the results of the "waste load allocation" applied to the Lower Fox River using the QUAL-II simulation model. This Table lists the amount of BOD_5 and suspended solids that each discharger could release such that 5 mg/l of dissolved oxygen would still be maintained under the 7Q10 flow and high summer temperatures. This Table lists the maximum discharges that can be allowed under critical conditions. Figure IV-18 gives useful information as to the size of the diurnal fluctuations that can be expected as a result of algae activity. A range of about 1.0 mg/l in the dissolved oxygen can be expected if the inflowing chlorophyll-a concentration is about 30 ug/l. If larger amounts of algae are present the fluctuation will be greater and 5 mg/l may be violated under nightime or prolonged overcast weather conditions.

It should be emphasized that Table IV-6 represents only one possible scheme for a "waste load allocation". In general most schemes will have to be fairly close to the one given. Tradeoffs in BOD loading between dischargers located very close together would be possible, however, increasing the discharge at a site several miles from another that was decreased would not be possible. Secondly, it is a matter of public interest as to whether a portion of the WLA should be saved for future municipal or industrial growth. If a portion is to be retained, a decision will have to be made as to how much each discharger is to be reduced beyond that allowed in Table IV-6. This type of process will require public participation to weigh all sides of this issue.

Up to this point, no mention has been made of a safety factor for the WLA discharge scheme. Table IV-6 leaves very little margin of error to meet the 5 mg/l dissolved oxygen standard under critical conditions. In light of this fact, a portion of the WLA should perhaps be withheld to allow for a reasonable margin of safety. Again it must be emphasized that a discharge permit that allows a maximum discharge of 1.5 to 3.0 times the average discharge will not be permissable if 5 mg/l DO is to be maintained. Maximum limits must be held as close to the average limit as possible. A slug load from two or three dischargers simultaneously could create a serious dissolved oxygen situation and may result in a fish kill. If part of the "waste load allocation" were withheld for future growth, then that portion would be able to act as a safety margin until such time as it is required by municipal or industrial expansion.

Ammonia reduction at all point sources will not significantly affect the DO profile. If nitrification had shown itself to be an important oxygen sink in the Lower Fox River, then nitrification at all sewage treatment plants would have supplied a useful safety factor in meeting the 5 mg/l dissolved oxygen level. Secondly, the concentration of NH_4+ is more readily absorbed by algae so a reduction in ammonia could work to slightly lower the algae activity along the river and in the Bay. The nitrification rates, however, appear to be very small along the Lower Fox River (about 0.07 day^{-1} base e at 20°C). The low nitrification rate in the river may arise from three sources. First, according to Tuffey et al (1974), nitrification generally will be the lowest in moderately large streams. This result is a conclusion based on the fact that nitrifying bacteria like to grow attached to a surface. A small stream supplies an adequate bottom surface area to volume ratio to affect good nitrification where as a large stream does not. In Green Bay itself, nitrification would be expected to occur, according to Tuffey, since the retention times are greatly increased and suspended material provide sufficient medium for nitrifying bacteria. The second reason for low nitrification rates results from the high average pH found along the Fox River. Nitrifying bacteria flourish in a relatively limited pH range. That range is usually reported to be between 7.0 and 8.0. Beyond either end of this range, the rate of nitrification drops off sharply. Low dissolved oxygen levels during the summer months also tend to inhibit nitrification. Nitrifying bacteria become inactive if the DO drops below 2.0 mg/l. All of these conditions reduce the importance of nitrification in the Lower Fox River, in regard to the oxygen balance.

The simulation output indicates that ammonia is coming mainly from organic nitrogen compounds flowing into the Fox River from Lake Winnebago. These organic nitrogen forms (particularly dead algae) can hydrolyze to ammonia. Ammonia can also be released from nitrogen compounds in the sediments. Because of the low nitrification rate, the ammonia tends to accumulate often reaching toxic concentrations. Ammonia is toxic to most species of aquatic organisms when it exists in the unionized form. The Water Quality Criteria of 1972 (Blue Book) recommends a concentration of unionized ammonia no greater than 0.02 mg/l. The toxicity problem is further amplified by the high pH in the river. The high pH pushes the ammonia-ammonium balance toward the unionized ammonia form. Thus ammonia toxicity appears to be a problem that may not be adequately correctable by point source controls.

On the other side of this question, nitrification may be partially enhanced by sufficient point source control of BOD for two reasons. Adequate treatment of wastes in treatment plants will raise the dissolved oxygen concentration such that low DO will no longer be a nitrification inhibiting factor. Secondly, closer control of the industrial dischargers may act to lower the average pH of the river. These two effects could be sufficient to stimulate nitrification to a point where ammonia will not tend to accumulate. The resulting increased nitrification could cause a slight lowering of the dissolved oxygen in the river.

At present, the QUAL-II model is capable of responding to the relationship between dissolved oxygen and nitrification. The simulation runs that were done for this project all showed a slightly higher concentration of nitrate when the dissolved oxygen was increased. Similarly, the denitrification rate is controlled by the dissolved oxygen level. Higher DO's tend to eliminate denitrification as a significant nitrogen sink in the model. These effects may combine to increase the inorganic nitrogen that flows down the Fox River and eventually into Green Bay.

A rudimentary sensitivity analysis was done with the QUAL-II model for the Lower Fox River. The results of this analysis are presented in Table V-1. The base line conditions are those used for the low flow and BPT simulation run. Table V-2 lists the base line headwater and reaction rate conditions. The most noteable effect in Table V-1 is the extreme sensitivity of the model to the benthic demand. Algae growth and respiration rates also have a marked affect on the oxygen level. In general, there is a correlation between oxygen and ammonia (higher oxygen leads to lower ammonia) and between oxygen and nitrate (lower oxygen means lower nitrate concentrations). The rate of organic nitrogen feedback to inorganic forms has a noticeable affect on the growth of algae. Oxygen levels respond to this change also. Organic nitrogen settling rate shows almost no effect of this sort.

TABLE V-1

Sensitivity of the QUAL-II
Model on The Lower Fox River
(Base Conditions are for Low Flow and BPT)

Parameter Altered	Mile Point	DO mg/1	BOD mg/1	Org-N mg/1	NH_3-N mg/1	NO_3-N mg/1	Chl-a mg/1
Base Condition No. Change	34.5	3.56	.96	1.995	.479	.099	27.15
	19.0	2.91	1.58	1.492	.799	.141	28.55
	0.1	1.83	2.20	.786	.928	.290	21.46
Benthic Demand Times 1.5	34.5	.74	.96	1.995	.490	.071	27.06
	19.0	.14	1.58	1.492	.833	.075	28.22
	0.1	.00	2.20	.784	1.030	.096	20.89
Benthic Demand Times 0.5	34.5	6.40	.96	1.995	.476	.113	27.20
	19.0	5.73	1.58	1.492	.789	.179	28.77
	0.1	5.21	2.20	.784	.901	.434	21.90
BOD Decay Times 2.0	34.5	3.00	.33	1.995	.481	.091	27.10
	19.0	2.42	.75	1.492	.804	.128	28.45
	0.1	1.11	1.62	.786	.935	.267	21.37
BOD Decay Times 0.5	34.5	4.40	1.71	1.995	.477	.105	27.17
	19.0	3.53	2.58	1.492	.795	.154	28.64
	0.1	2.50	2.86	.786	.922	.312	21.56
Org-N Decay Times 2.0	34.5	3.62	.96	1.733	.729	.106	29.24
	19.0	3.11	1.58	1.113	1.137	.176	33.05
	0.1	2.06	2.20	.429	1.182	.406	25.69
Org-N Decay Times 0.5	34.5	3.52	.96	2.136	.343	.095	25.76
	19.0	2.74	1.58	1.723	.589	.121	25.19
	0.1	1.52	2.20	1.080	.697	.206	17.50
Org-N Settling Times 2.0	34.5	3.56	.96	1.852	.468	.099	27.09
	19.0	2.90	1.58	1.276	.763	.139	28.26
	0.1	1.84	2.20	.556	.824	.272	20.71
Org-N Settling Times 0.5	34.5	3.56	.96	2.071	.485	.099	27.18
	19.0	2.92	1.58	1.615	.819	.142	28.70
	0.1	1.83	2.20	.941	.991	.300	21.85
Ammonia Decay Times 2.0	34.5	3.44	.96	1.995	.441	.115	26.96
	19.0	2.72	1.58	1.492	.693	.198	28.04
	0.1	1.33	2.20	.784	.673	.402	20.72
Ammonia Decay Times 0.5	34.5	3.63	.96	1.995	.500	.090	27.25
	19.0	3.03	1.58	1.492	.861	.107	28.82
	0.1	2.24	2.20	.787	1.112	.191	21.86

TABLE V-1 (continued)

Parameter Altered	Mile Point	DO mg/l	BOD mg/l	Org-N mg/l	NH_3-N mg/l	NO_3-N mg/l	Chl-a mg/l
Algae Growth Times 2.0	34.5	4.85	.96	2.011	.463	.104	54.15
	19.0	5.55	1.58	1.563	.717	.163	101.02
	0.1	2.07	2.20	1.079	.781	.314	99.99
Algae Growth Times 0.5	34.5	2.93	.96	1.989	.485	.096	18.24
	19.0	1.54	1.58	1.472	.827	.121	11.27
	0.1	0.0	2.20	.717	1.093	.078	3.10
Algae Respiration Times 2.0	34.5	2.46	.96	2.005	.485	.092	12.73
	19.0	.89	1.58	1.486	.835	.106	5.86
	0.1	0.0	2.20	.719	1.137	.055	.65
Algae Respiration Times 0.5	34.5	4.20	.96	1.984	.476	.102	39.64
	19.0	4.43	1.58	1.481	.777	.157	59.28
	0.1	3.15	2.20	.816	.855	.374	81.95
1500 CFS Flow Rate	34.5	4.93	1.32	2.171	.333	.099	26.84
	19.0	4.31	1.66	1.801	.594	.117	26.04
	0.1	3.56	1.74	1.162	.844	.221	21.00
700 CFS Flow Rate	34.5	2.80	.76	1.875	.576	.097	27.74
	19.0	2.08	1.50	1.308	.908	.153	31.04
	0.1	.67	2.50	.619	.923	.284	20.96
Temperature 84°F	34.5	2.74	.86	1.968	.519	.086	27.47
	19.0	2.17	1.44	1.452	.875	.105	29.70
	0.1	1.11	2.11	.746	1.065	.201	21.81
Temperature 72°F	34.5	5.11	1.19	2.042	.397	.133	26.69
	19.0	4.37	1.86	1.566	.636	.234	26.77
	0.1	3.23	2.38	.865	.633	.500	20.69
Temperature 35°F 100 Lang/Day	34.5	10.47	2.12	2.176	.308	.101	24.54
	19.0	11.17	3.21	1.790	.562	.114	20.00
	0.1	9.73	3.35	1.159	.771	.161	12.39

TABLE V-2

Base Line Conditions for Sensitivity Runs *

Inflow Concentrations	
Flow	912 CFS
DO	9.0 mg/1
BOD	2.0 mg/1
Org-N	2.5 mg/1
NH_3-N	.04 mg/1
NO_3-N	.10 mg/1
PO_4-P	.20 mg/1
Chl-a	30 mg/1
Temp.	80°F

Reaction Rates (Base e)	
BOD Decay	.306/day
Org-N Decay	.035/day
Org-N Settling	.025/day
NH_3-N Decay	.07/day
Algae Growth	1.0/day
Algae Respiration	.2/day
Algae Settling	1.0 ft/day

* For benthic demands see Table IV-1.

Nutrients and Primary Production

The nutrient balance in Green Bay is controlled by several factors. The Lower Fox River is the largest single source of nutrients to Green Bay. Large quantities of nitrogen and phosphorus are continually being supplied to the Bay. Much of the nutrients that enter the Bay arrive during the spring runoff period. As much as 50% of the yearly inflowing nutrients may arrive during the spring period. Figure V-1 illustrates the Lower Fox River hydrograph for the period of this study. The peak flows in April, May and June carry high nutrient loads washed off of partially frozen ground. In addition, to the Lower Fox River other rivers such as the Oconto, Peshtigo and Menominee supply nutrients. These nutrients stimulate extensive algae blooms through out the Lower and Middle area of the Bay.

The algae growths represent one portion of a complicated nutrient cycling process. This process is characterized by algae blooms in spring and early summer that appear to be nitrogen limited. The nutrients consumed in this phase can be recycled (particularly in shallow areas) or it can be carried out of the growth zone by settling of dead algae cells. This phase is followed by an extensive bloom of nitrogen-fixing algae. The extent of the second bloom appears to be phosphorus limited. The nitrogen-fixing algae (Anabaena and Aphanizomenon) can contribute significant quantities of nitrogen to the Bay during their bloom period. The input of nitrogen from the nitrogen-fixing algae allows the nitrogen dependent forms to once again bloom. The rotation of algae types occurs at least twice during the summer period. This pattern was first observed by Vanderhoef et al (1972, 1974). The surveys taken by the Wisconsin DNR during the summer of 1974

FIGURE V-1

Lower Fox River Hydrograph During the Green Bay Study Period
(Flows in cfs)

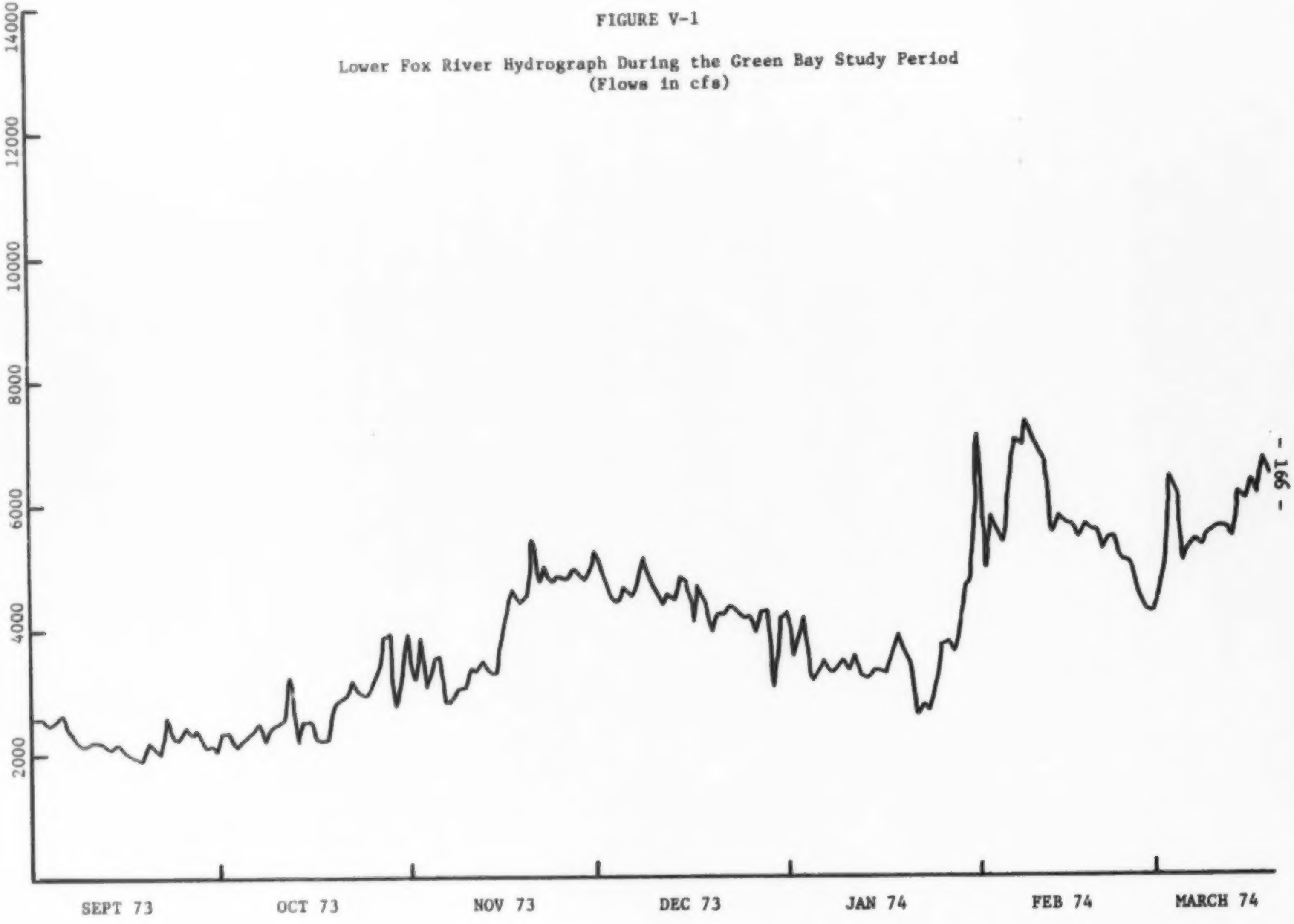
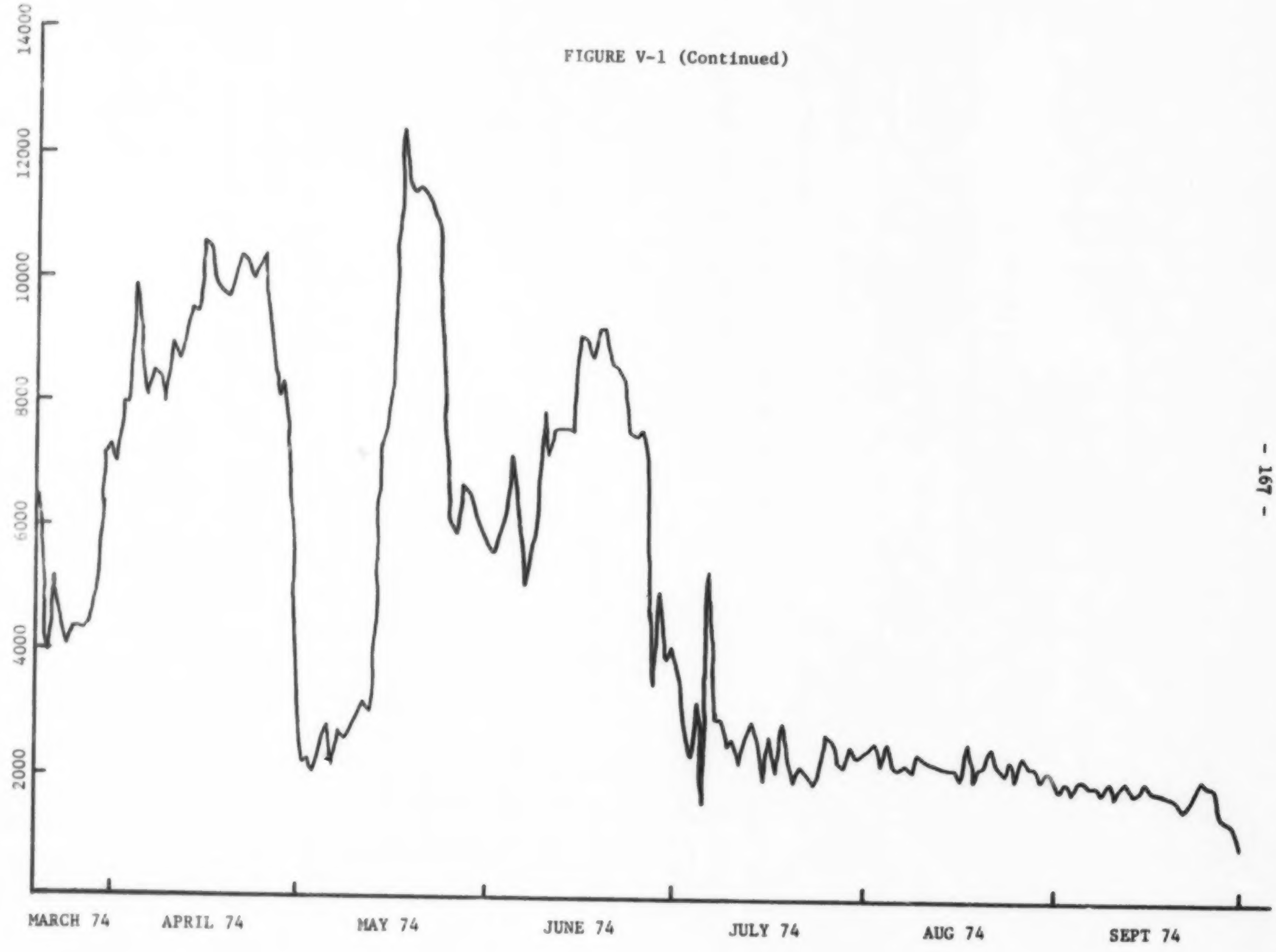


FIGURE V-1 (Continued)



support this cyclic nature of the algal types. This pattern is violated in the Lower Bay only in close to the mouth of the Fox River. High inorganic nitrogen concentrations exist in this area all year around. For that reason, nitrogen fixing algae never predominate.

An important aspect of the nutrient cycles in Green Bay concerns the sediment-water exchange mechanisms. These exchange mechanisms tend to stablize the phosphorus concentration in the Bay. The 1974 survey data suggests that an important source of phosphorus may be the resuspension of phosphorus containing bottom sediments in the shallow portions and along the shore in the Bay. The phosphorus released in this way can become available for primary production if the necessary chemical reactions take place to transform the phosphorus into soluable forms. This process appears to take place faster than algal uptake during the spring and early summer when growth rates are still low due to cold temperatures. Later on, the growth of algae may overtake the resoluabilization process causing phosphorus limited primary production. This explanation is consistent with the observed increase of phosphorus in May and June, followed by a gradual decrease for the rest of the summer.

Phosphorus also settles into the sediments. Sinking algal cells and chemical precipitation carries phosphorus into the sediments. In the deeper areas of the Bay the sediments usually act as a net sink for phosphorus. However, under anaerobic conditions phosphorus is resoluabilized at a rate that may be 10 times faster than under aerobic conditions. Survey data in February 1974 indicated slight increases in the soluable phosphorus compounds in the same region where low dissolved oxygen was detected.

Ammonia levels in Green Bay don't appear to be a problem except for a small area very close to the mouth of the Lower Fox River. When the temperatures are high, the ammonia level drops to almost unmeasurable levels over the entire Bay. Nitrification and algae uptake during the summer account for this low level of ammonia. Toxicity from free ammonia in Green Bay occurs only within a few hundred yards of the mouth of the Fox River where inflowing levels are high. During colder winter temperatures the higher ammonia levels from the Lower Fox River penetrate into the Bay for as much as 10 to 20 miles. Ammonia measurements near Red Banks showed 0.6 mg/l during the February survey of 1974. The higher levels of ammonia during the winter months do not cause a toxicity problem, however, due to the low temperatures of the water

It is interesting to observe the rather dramatic increase in nitrate in the deeper water of the Bay during the summer. The nitrate can be coming from at least two sources. First, ammonia released from the sediments is trapped below the thermocline. This ammonia eventually undergoes nitrification to nitrate since there is not enough light in the deeper waters for primary production. Secondly, sinking algal cells release nitrogen compounds that will also nitrify. The accumulated nitrate, however, will not become available to algae until the fall turnover when the water mixes.

The results of the Lower Fox River modelling effort indicated that higher dissolved oxygen levels may result in slightly higher concentrations of inorganic nitrogen entering Green Bay. If this is true, then the early summer blooms of nitrogen fixing algae may be delayed due to the prolonged predominance of other forms of phytoplankton. The result would be an upset of the cyclic pattern of algal species observed by Vanderhoef et al (1972, 1974) and the Wisconsin DNR.

Improved treatment at municipal sewage plants may reduce the total nitrogen loading to the Fox River and thereby offset the rise in nitrogen entering Green Bay. Effective biological treatment, removing combined sewers and ending sewage overflow bypassing would result in reductions in both total nitrogen and total phosphorous loading along the Lower Fox River.

SECTION VI

VI. SUMMARY AND RECOMMENDATIONS

The following list is a summary of the major findings and recommendations of this study:

1. The most critical dissolved oxygen condition in the study area appears to be the summer low flow period in the Lower Fox River. Substantial improvements at point source discharges beyond "Best Practicable Treatment" will be required to maintain a dissolved oxygen level above 5.0 mg/l at all times. BPT levels of treatment are expected to violate variance dissolved oxygen standards at three locations along the river during low flow and high temperatures.

2. The winter ice cover period (January to early April) has caused frequent low dissolved oxygen problems in Lower Green Bay in the past. High organic loadings, together with nearly zero reaeration, have caused as much as 150 square miles of the Lower Bay to suffer severe DO depletion. The survey of February 1974, a part of this study, indicated a 50 square mile area with 5 mg/l of DO or less along the eastern half of the Bay from Point Sable to the Renard River.

3. The methods presented in this report show that dissolved oxygen modelling of the winter condition in Lower Green Bay can be accomplished with a sufficient degree of accuracy to allow conclusions to be made for various abatement schedules.

4. Dissolved oxygen modelling of the winter ice cover period in Lower Green Bay indicates that "Best Practicable Treatment" at all point sources along the Lower

Fox River will be sufficient to maintain 5.0 mg/l of dissolved oxygen in Lower Green Bay during the winter period. On the basis of this modelling, it is recommended that the dissolved oxygen variance on Lower Green Bay be removed effective 1977 when "Best Practicable Treatment" is to be met.

5. Long term BOD (60 days) monitoring should be considered in the Green Bay area as a means of determining the changes that will take place in the BOD load to Green Bay during the compliance period with the present permits. This is especially important since the long term BOD is the prime factor in determining the severity of the winter dissolved oxygen deficit in Green Bay.

6. Review of the location of the Green Bay monitoring station is highly recommended. At present, sampling is done at the Mason Street Bridge in Green Bay. This location is upstream of three large paper mill effluents and the Green Bay sewage effluent. The concentrations reported at this station do not reflect accurate representations of the actual loading to Green Bay. Unfortunately, it is probably not possible to obtain a representative sample in this area because of the Green Bay seiche effects in the River and the location of the new Green Bay sewage plant effluent. It may be appropriate to report concentrations at the mouth of the Fox River (i.e., true loading to Green Bay) by separately considering the addition from the downstream effluents.

7. Dissolved oxygen modelling of the Lower Fox River indicates that an average reduction of the 37% below "Best Practicable Treatment" will be required to maintain 5.0 mg/l of dissolved oxygen during the low flow and high temperature period. The waste load allocation developed by the model takes into account the suspended solids reductions at each discharge location.

Any future modifications to permits affected by the load allocation should use the waste load allocation as a basis of the permit. This discharge scheme has been developed to maintain 5.0 mg/l of dissolved oxygen in the Lower Fox River. Daily maximum discharges allowable in the permits should be less than one and one-half times the daily average allowed discharge to avoid shock loads that could cause a substantial fish kill.

8. The largest single source of nitrogen in the Lower Fox River appears to be Lake Winnebago. Ammonia toxicity may continue to be a problem in the Lower Fox River during high temperatures, even if treatment plants are required to remove ammonia from their effluents. Since nitrification in the river does not appear to a substantial degree, little dissolved oxygen change will result from removing ammonia.

9. Higher dissolved oxygen levels in the Lower Fox River may tend to increase the concentration of inorganic nitrogen entering Lower Green Bay as a result of decreased denitrification rates. This may be offset by improved treatment and elimination of bypassing from cimbined storm sewers.

Increased monitoring of nitrogen forms should be included in the discharge permits especially for sewage treatment plants. Monitoring should include total organic and ammonia nitrogen forms. This type of monitoring will allow future evaluation of nitrification as a means of reducing ammonia levels in the Lower Fox River.

10. It is difficult to determine what the phosphorus concentration will do in the future. All treatment plants serving more than 2,500 people are now required to remove 85% of the total phosphorus in the effluent. Bypassing and poor

treatment at temporary add-on facilities have reduced the effectiveness of the phosphorus removal program. New treatment systems should correct this problem at sewage treatment plants. On the other hand, biological treatment of pulp and paper mill wastes may require nutrient additions, including phosphorus. Proposed regulations will limit these discharges to a concentration of 1.0 mg/l or less. The net effect is unclear at this time, but will probably not be significant compared to the phosphorus loading from Lake Winnebago.

11. A monthly monitoring station, similar to other monthly monitoring stations maintained by the DNR, was begun in the Neenah-Menasha area as a result of an early recommendation of this project. A monitoring station in Green Bay has been sampled monthly since 1961. Results from the new station will allow determination of the net effects of discharges along the Lower Fox River.

12. Sampling in Green Bay during the summer of 1974 revealed total phosphorus concentrations not significantly different from those observed in 1973. Phosphorus concentrations in 1971 were significantly higher in the Inner Bay than those observed in 1974. The largest buildup of phosphorus in the Bay occurs during the spring season, when sediments are stirred by spring storms and high flows wash large quantities of phosphorus into the Bay.

13. Nitrogen forms fluctuated widely over the year. Several fold changes in nitrate concentration were particularly evident. Nitrate appears to build up in the bottom waters of the deep areas over the course of the summer. The most significant source of this nitrogen is probably from sinking algae cells.

14. Dissolved oxygen concentrations in the Lower Bay recover rapidly from the low levels of the Fox River during the summer months. Except for a small area

in the immediate vicinity of the Fox River mouth, the dissolved oxygen level was not a problem. Some readings taken near the bottom also had depressed DO's probably as a result of decaying algae cells. The extent of this area was limited.

15. The fluctuations in algae species in the lower third of Green Bay are dramatic. Blooms in blue-green algae (Aphanizamenon) predominated in July. June and August saw most of the Bay dominated by Oscillatoria. Aphanizamenon are capable of fixing nitrogen and, therefore, are more competitive when inorganic nitrogen falls to a low level. The extent of the Aphanizamenon bloom is probably controlled by the available phosphorus concentration. Large quantities of nitrogen are added to the Bay by nitrogen fixing algae.

16. The concentration of chlorophyll-a generally increased during the summer; however, a larger fraction was in phaeo-pigments (inactive or dead chlorophyll-a) in late summer.

17. Benthic oxygen uptake in Green Bay above Long Tail Point and Sable Point will not change significantly as a result of "Best Practicable Treatment". In the Inner Bay (near the Fox River mouth), improved treatment at several paper mills and at the Green Bay sewage treatment plant should have a dramatic effect on the condition of the Inner Bay in the next few years, particularly in regard to sludge deposits and benthic fauna.

18. A follow-up study should be carried out in 1978 to 1980. The present permits for "Best Practicable Treatment" will be met by that time. Emphasis should be placed on winter dissolved oxygen in the Bay and summer conditions in the river. Measurements of benthic demands should also be carried out to determine the effect

of reduced loading on existing sludge deposits. Sufficient information should be available by then from monthly monitoring data in Neenah-Menasha and Green Bay to assess the value of increasing nutrient control along the Lower Fox River.

SECTION VII

BIBLIOGRAPHY

Crevensten, Dan, Stoddard, A., Vajda, G.

1973. Water Quality Model of the Lower Fox River, Wisconsin. United States Environmental Protection Agency Enforcement Division.

Ditoro, D. M.

1969. "Predicting the Dissolved Oxygen Production of Planktonic Algae." Notes for Manhattan College Summer Institute in Water Pollution Control, Manhattan College, Bronx, New York.

Epstein, E. F., Bryans, M. A., Mezei, D. and Patterson, D. J.

1974. Lower Green Bay: An Evaluation of Existing and Historical Conditions. Wisconsin Department of Natural Resources. U.S. Environmental Protection Agency. EPA-905/9-74-006. August 1974.

Holland, R. E.

1968. "Correlation of Melosira Species with Trophic Conditions in Lake Michigan." Limnol. & Oceanog. 13:555-557.

Hutchinson, G. E.

1957. A Treatise on Limnology. John Wiley and Sons, Inc., New York.

Lee, A. Genet, Smith, Donald J. and Sonnen, Michael B.

1974. "Computer Documentation for the Dynamic Estuary Model." Water Resources Engineers, Inc., Contract No. 68-01-1800.

McKeown, J. J., Benedict, A. H. and Lake, G. M.

1968. Studies on the Behavior of Benthal Deposits of Paper Mill Origin, National Council Technical Bulletin, No. 219.

Modlin, R. F. and Beeton, A. M.

1970. "Dispersal of Fox River Water in Green Bay, Lake Michigan" Proc. 13th Conf. Great Lakes Res. 1970.468-476.

Norton, W. R., Roesner, L. A., Evenson, D. E. and Monser, J. R.

1974. Computer Program Documentation for the Stream Quality Model Qual-II. Water Resources Engineering. U.S. Environmental Protection Agency, Contract No. 68-01-0713.

O'Connor, D. J., Thomann, R. V., and DiToro, D. M.

1973. Mathematical Modelling of Natural Systems, Manhattan College, New York, New York.

O'Connor, D. J., Thomann, R. V., DiToro, D. M.

1973. Dynamic Water Quality Forecasting and Management, U.S. Environmental Protection Agency. Office of Research and Development. EPA 660/3-73-009.

Palmer, C. M.

1959. Algae in Water Supplies, U.S. Department of Health, Education and Welfare, PHS Publ. No. 657.

Patterson, D. J.

1973. Results of a Mathematical Water Quality Model of the Lower Fox River, Wisconsin. Wisconsin Department of Natural Resources, Water Quality Evaluation Section.

Prescott, G. W.

1951. Algae of the Western Great Lakes Area, Cranbrook Press, Cranbrook Inst. of Science.

Quirk, Lawler and Matusky Engineers.

1969. Development of a Computerized Mathematical System Model of the Lower Fox River From Lake Winnebago to Green Bay. Wisconsin Department of Natural Resources.

Riley, G. A.

1956. "Oceanography of Long Island Sound 1952-1954. II Physical Oceanography," Bull. Bingham Oceanog. Coll. 15, 15-46.

Sager, Paul & Wiersma, Jim

1971. University of Wisconsin, Green Bay, Unpublished Data.

Sager, P. E. & Wiersma, J. H.

1972. "Nutrient Discharges to Green Bay, Lake Michigan from the Lower Fox River." Proc. 15th Conf. Great Lakes Res. 1972, 132-148.

Smith, Gilbert M.

1933. The Fresh-Water Algae of the United States, McGraw-Hill Publ. Co. New York.

Srinath, E. G., Prakesam, J.B.S. and Loehr, R. C.

1974. A Technique for Estimating Active Nitrifying Mass and Its Application in Designing Nitrifying Systems. 29th Purdue Industrial Waste Conference, Purdue University, West Lafayette, Indiana.

Thomann, R. V.

1972. Systems Analysis and Water Quality Management, Environmental Science Services Division, Environmental Research and Applications, Inc., New York.

Tuffey, T. J., Hunter, J. V. and Matulewich, V. A.

1974. Zones of Nitrification. Water Resources Bulletin, American Water Resources Association, Vol. 10, No. 3, pp. 555-564.

Vanderhoef, L. N., Dana, B., Emerich, D., and Burris, R. H.

1972. Acetylene Reduction in Relation to Levels of Phosphate and Fixed Nitrogen in Green Bay. _New Phytol_. 71:1097-1105.

Vanderhoef, L. N., Huang, C. Y., and Musil, R.

1974. Nitrogen Fixation (acetylene reduction) by Phytoplankton in Green Bay, Lake Michigan, in Relation to Nutrient Concentration. Limnol and Oceanogr. 19:119-125.

Water Quality Criteria 1972.

1973. A Report of the Committee on Water Quality Criteria, At the Request of the Environmental Protection Agency.

Weber, C. I.

1971. A Guide to the Common Diatoms at Water Pollution Surveillance System Stations, U.S. Environmental Protection Agency, Natl. Environ. Res. Ctr.

Wisconsin Department of Natural Resources.

1974. Report on the Waste Load Assimilation Capacity of the Oconto River Near Oconto Falls, Wisconsin. Water Quality Evaluation Section.

Wisconsin Department of Natural Resources.

1973. State of Wisconsin Surface Water Quality Monitoring Data 1969-1972.

Wisconsin Department of Natural Resources.

1972. Summary Report on the Water Quality and Wastewater Discharges During the Summer of 1972. Water Quality Evaluation Section.

Zanoni, A. E.

1969. Secondary Effluent Deoxygenation at Different Temperatures. Journal of the Water Pollution Control Federation, 41:640-659.

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SECTION VIII

APPENDIX A

Planktonic Algae Survey on Green Bay, 1974

The plankton suspended in water were collected in February, May and June, 1974, in a 2 liter Kemmerer at a depth of 1 to 2 meters, preserved with Merthiolate and concentrated by filtration. Samples taken in July, August and September were collected in a Clark-Bumpus plankton sampler, preserved with Formalin and concentrated by sedimentation. All samples were counted by a modified drop-count method. Biomass estimates and total volatile solids were also determined.

The water samples for planktonic algae examination were concentrated to 100 ml. Each sample was stirred and mixed thoroughly; a calibrated pipette was used to draw-off and discharge 0.05 ml of sample onto a microscope slide on which a 22 mm square chamber had been constructed and which gave an even distribution of the sample when covered with a 22 mm coverslip. Each sample was examined under 430X magnification to identify the organisms present and then counts were made at 100X magnification. Twenty-five ocular fields were examined in cases of sparse occurrences and 10 Whipple fields were examined when algae concentrations were greater. A constant pattern of examination was used throughout the study.

Cells touching the top and right side of the Whipple grid were counted while those touching the bottom and left side were not. Likewise when the full ocular field was counted those cells which extended from the right side of the field were counted, while those which extended beyond the left side were excluded.

Algae were counted as frustules, single cells, filaments or colonies (See Table III-2, Genera of Algae Observed). In some cases the species observed were not tabulated because they did not occur within the Whipple grid, but were recorded as having been observed. Filaments were counted as one regardless of their length and colonies were counted as one regardless of the size of the colony. In some cases a colony was considered to have a given size (See Table III-2). In the case of Microcystis and Gomphospheria, an average size was determined for counting purposes. Therefore, these criteria may have caused a lower count than would otherwise have been obtained if definite colony and filament sizes had been previously determined for all species.

For convenience, Euglena, colonial and single cells of green algae which seldom occurred, and those called Chlorococcales were collectively tabulated as green algae, while filamentous green algae were collectively tabulated as Ulotrichales.

The techniques used for identification are described in Prescott (1951), Palmer (1959), Smith (1933), and Weber (1971).

SECTION VIII

APPENDIX B

Description of Methods for Chemical Analysis of Water Samples

Ortho-Phosphorus

Water samples were filtered within 12 hours through 0.45u Millipore filters. The filtrate was analyzed by Technicon Procedure 155-71W using an Autoanalyzer II System. Results were reported as mg/l phosphorus.

Total-Phosphorus

Unfiltered samples were digested using the persulfate digestion procedure described in standard methods (Autoclaved for 30 minutes at 121°C). The digested samples were then carried through the ortho-phosphorous procedure described above. Results were reported as mg/l total phosphorous.

Suspended Solids

A measured volume of sample was filtered through preweighed 0.45u Millipore Filters. The filter and the collected material were dried overnight at 90°C and then reweighed. The quantity of suspended matter in a one liter of water was calculated from the increase in weight and volume of the sample filtered. Results were reported as mg/l suspended solids.

Biochemical Oxygen Demand

The BOD, a measure of the amount of dissolved oxygen utilized by micro-organisms to stablize the organic material in a water, is made under controlled conditions usually over a 5-day period at 20°C with nutrients and without light. The sample dilution factor multiplied by the decrease in dissolved oxygen is reported as the water's BOD.

Chlorides

Determined by titration with silver nitrate solution to the chromate endpoint (Mohr Method).

Organic Nitrogen (Kjeldahl)

Unfiltered samples (30 ml) were digested according to standard methods using 300 ml flasks. The digest was made alkaline and the ammonia immediately distilled off and collected in Boric Acid solution containing a mixed indicator. The distillate were back titrated with standardized sulfuric acid. Organic-nitrogen values reported were obtained by subtracting ammonia nitrogen values (see below) from the total ammonia nitrogen in the distillate. Results were reported as mg/l organic nitrogen.

Ammonia Nitrogen

Samples were filtered through 0.45u Millipore Filters. The filtrate was analyzed for ammonia content by Technicon Auto Analyzer procedure 98-70W. Results were reported as mg/l ammonia-nitrogen.

Nitrate and Nitrite Nitrogen

Samples were filtered through 0.45u Milliport Filters. The filtrate was analyzed for nitrate or nitrite by using Technicon Auto Analyzer II procedure 100-70W. Results were reported as mg/l nitrate or nitrite nitrogen.

Chlorophyll-a plus Pigments

An unfiltered sample (400 ml) was filtered and concentrated using 10 u bolting cloth. The collected algae were then further concentrated by collecting on 0.45 u Millipore Filters. The filter and the algae were then homogenized in 25 ml of 90% acetone-10% water solution by grinding the mixture with an air driven mortar and pestle. The solution was centrifuged and the absorbance of the resulting solution was measured at 750 nm and 665 nm. After these measurements the samples were acidified with 0.02 ml of concentrated HCl and the absorbances again measured at 750 nm and 665 nm. All absorbances measurements at 750 nm were subtracted from 665 nm reading to correct for turbidity remaining in the sampler. Results were calculated and reported as mg/l m^3 chlorophyll-a and mg/l m^3 pheophytin (physiologically inactive pigments). Calculations were **made using the equations** on p. 749 of standard methods except that the volume of original filtrate is substituted for A in the given equations.

Summary of Analytical Methods Used
for DNR Water Samples

Parameter	Method	Reference Number
Ortho-phosphorus	Auto Analyzer AAII 155-71W	1
Total-phosphorus	Persulfate Digestion-followed by Ortho-P procedure	2, 1 P. 526
Suspended Solids	Gravimetric	2
Organic Nitrogen	Semimicro Kjeldahl	2
Nitrate Nitrogen	Auto Analyzer AAII 100-70W	1
Nitrite Nitrogen	Auto Analyzer AAII 100-70W	1
Ammonia Nitrogen	Auto Analyzer AAII 98-70W	1
Chlorophyll-a	Chlorophyll-a in the presence of Pheophytin-a	2 P. 748

References:

(1) Technical Publication No. TJ1-0268 - Technicon Auto Analyzer II Systems - Technicon Industrial Systems - Technicon Instruments Corporation - Tarrytown, New York.

(2) "Standard Methods for the Examination of Water and Waste Water" 13th Edition, 1971. APHA-AWWA-WPCF.

APPENDIX C

Benthic Oxygen Demand

Considerable effort has been applied recently to try to understand the kinetics of oxygen consumption and BOD decay. However, it is usually impossible to account for the observed deficit by BOD decay alone. Classical BOD sag equation (Streeter-Phelps type) usually do not generate sufficient oxygen deficit. This is particularly true for paper mill wastes when the observed BOD_5 loading is input to the equations with the observed decay rate. Most researchers have attempted to explain this discrepancy by pointing to sludge banks and attributing the missing oxygen to benthic consumption. There is no doubt that paper mill sludge deposits can exert a considerable oxygen demand on a river. However, it is extremely difficult to estimate the exact extent of the benthic demand. Several laboratory and field measuring techniques have been cited in the literature. All of these methods are time consuming, costly and the results are subject to considerable error.

For paper mill deposits, oxygen demand from sludges has been estimated to lie between 2.0 and 10.0 grams of O_2 per square meter per day. (Thomann 1972). Measurements taken in the Lower Fox River indicate values in and around this range. Table C-1 lists the benthic demand values at several locations measured during the fall of 1972 on the Lower Fox River. These values represent laboratory measurements on samples that were extracted from the river with a Peterson dredge. The samples were placed in 2.5 liter bottles with a closed circuit water circulation system attached. The flowing water moved past a DO probe which was attached to a strip chart recorder. The entire apparatus was incubated at 20°C. The samples were allowed to stablize for at least 2 days before a reading was started.

TABLE C-1

Benthic Oxygen Demand in the Lower Fox River

Location	Sample No.	Benthic Demand GR-O_2/M^2/DAY
Neenah-Menasha Area	10a	7.75
	10b	11.28
	10c	9.59
Below Appleton Dam	8a	5.66
	8b	5.38
	8c	4.21
Above Kaukauna	1a	4.78
	1b	3.99
	1c	1.98
	2a	7.33
	2b	9.02
	2c	8.78
Below Kaukauna	3a	4.09
	3b	6.17
Near Wrightstown	4a	3.96
	4b	3.25
	4c	2.33
Above De Pere Dam	5a	4.68
At the Fox River Mouth	6a	1.86

A second set of benthic samples was taken in September, 1974. These samples were obtained from 7 locations in the Lower Bay. The procedure discussed above was used to evaluate the benthic demand at these locations. The results are shown in Figure C-1. The values shown are considerably below the rates measured in the Lower Fox River in 1972. The consistency of the muds varied widely at the shown locations. Below Grassy Island the samples consisted of non-cohesive fluid-like silt. The sample off Red Banks had the characteristics of highly cohesive clay. Above Long Tail Point the sample contained a high amount of fine sand. The sample off the end of Long Tail Point contained mostly large-grained sand.

In addition to these laboratory measurements, two attempts were made to measure the benthic oxygen demand in situ. A large rectangular metal box was constructed for this purpose. The box was 2' x 2' x 1'. A flange was attached around the bottom to support the box and prevent it from sinking too deeply into the sediments. A Yellow Springs DO probe with a mixing device was sealed in the box. Figure C-2 is a diagram of the apparatus. A float was anchored above the location of the box and the instrumentation was attached to the float. The instruments consisted of the DO probe, strip chart recorder and battery for the mixing device. The box was lowered from the surface (no diver was used) and left in place about 12 hours. The results at the two locations are shown in Figure C-1. Both values are several times higher than the laboratory measurements. Since the test was only run for 12 hours, the unusually high values may be the result of suspended sediments trapped in the box when it was put in place. From these results it appears that it would be desirable to allow a day or two for this condition to clear itself before taking a measurement. In order to do this, a method would have to be devised to change the water or raise the DO before beginning the measurement run.

FIGURE C-1
Benthic Oxygen Demand in Lower Green Bay
in GR O_2/m^2/Day

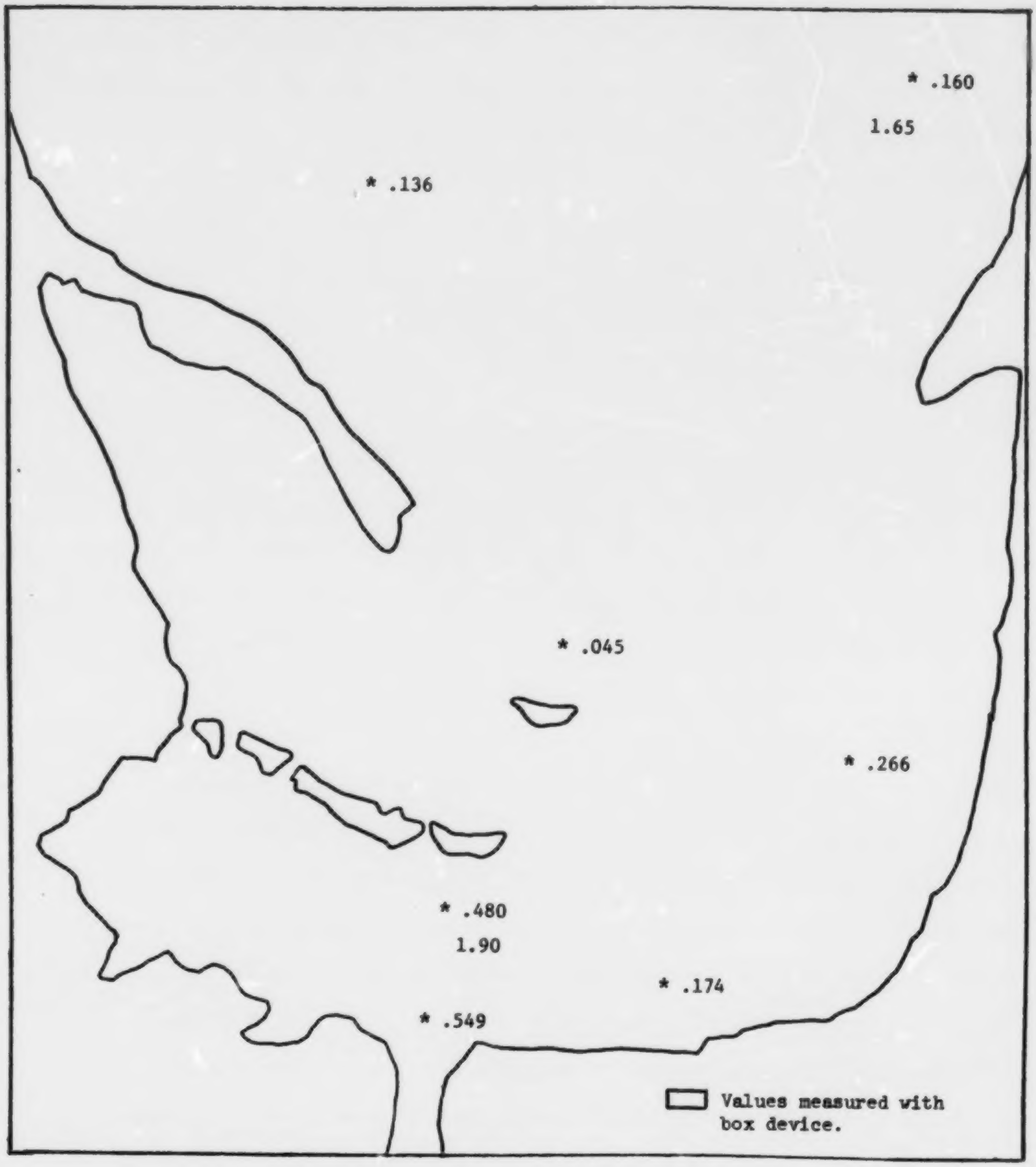
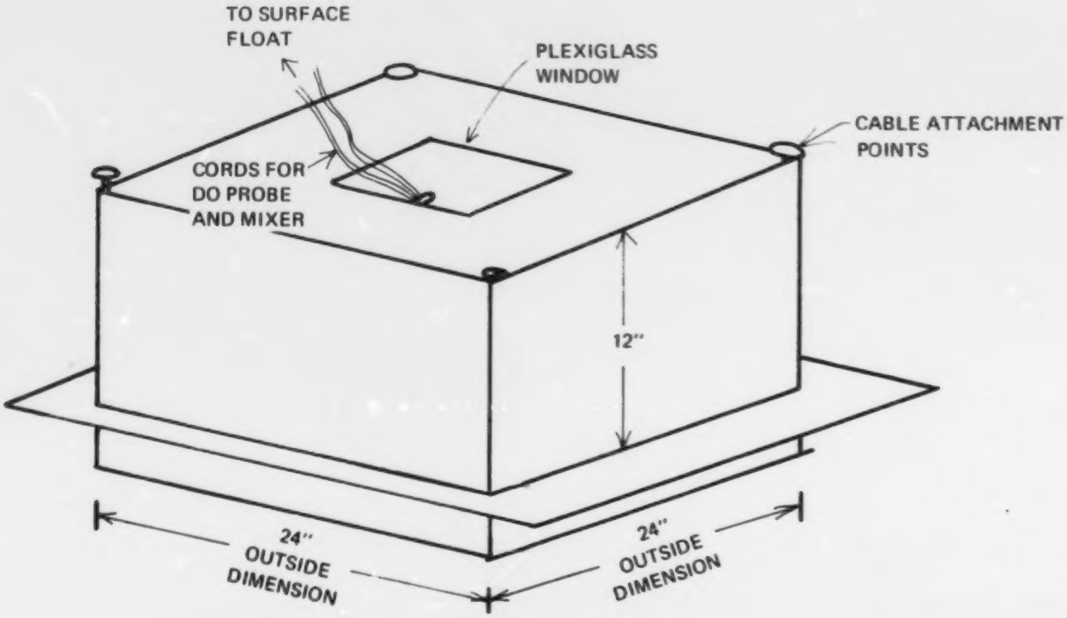

* .160
1.65
* .136
* .045
* .266
* .480
1.90
* .174
* .549
Values measured with box device.

FIGURE C – 2

BENTHIC OXYGEN DEMAND MEASURING DEVICE


TO SURFACE FLOAT
PLEXIGLASS WINDOW
CABLE ATTACHMENT POINTS
CORDS FOR DO PROBE AND MIXER
12"
24" OUTSIDE DIMENSION
24" OUTSIDE DIMENSION

METAL IS 1/8" THICK

AREA = 3639.11 cm^2

VOLUME ABOVE FLANGE = 109.76 LITERS

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APPENDIX D

GBQUAL Program Documentation

Program History

GBQUAL as used in the Green Bay study consists of six FORTRAN computer routines. These six routines are derived from the "Dynamic Estuary Model" documented by Lee et al., Water Resources Engineers (WRE) in May 1974 under contract no. 68-01-1800. The model, as described in WRE's report, has been significantly altered to fit the Green Bay situation. Since the program changes have been so extensive, a relatively intense program description is necessary to benefit future users. This description is not intended to fully replace the documentation prepared by WRE. Future users of this model are encouraged to obtain a copy of WRE's documentation if they plan to do extensive work with the model and especially if they will require program modifications. The enclosed descriptions, however, should be complete enough to: (1) allow a user to prepare a data deck and run the model; (2) understand the basic flow of information and know where various calculations are made; (3) acquaint the user with the capabilities and the limitations of GBQUAL. With this in mind, the following sections will present a general description of the quality model plus a detailed description of each subroutine. In addition, a separate section describes the data input setup required to run GBQUAL. The last section describes the theoretical considerations used in formulating the reactions allowed by GBQUAL. This section includes a table of estimated parameter ranges for the various coefficients used in the model.

General Description of the Green Bay Model

The water quality model attempts to simulate the significant physical, chemical and biological reactions that take place in Green Bay. The quality model was constructed to route the following constituents through the Bay:

1. Coliform
2. Carbonaceous biochemical oxygen demand
3. Dissolved oxygen
4. Organic nitrogen (not in phytoplankton)
5. Ammonia nitrogen
6. Nitrite nitrogen
7. Nitrate nitrogen
8. Soluable phosphate phosphorus
9. Total nitrogen as a conservative (or any conservative)
10. Phytoplankton 1 biomass
11. Phytoplankton 2 biomass
12. Temperature

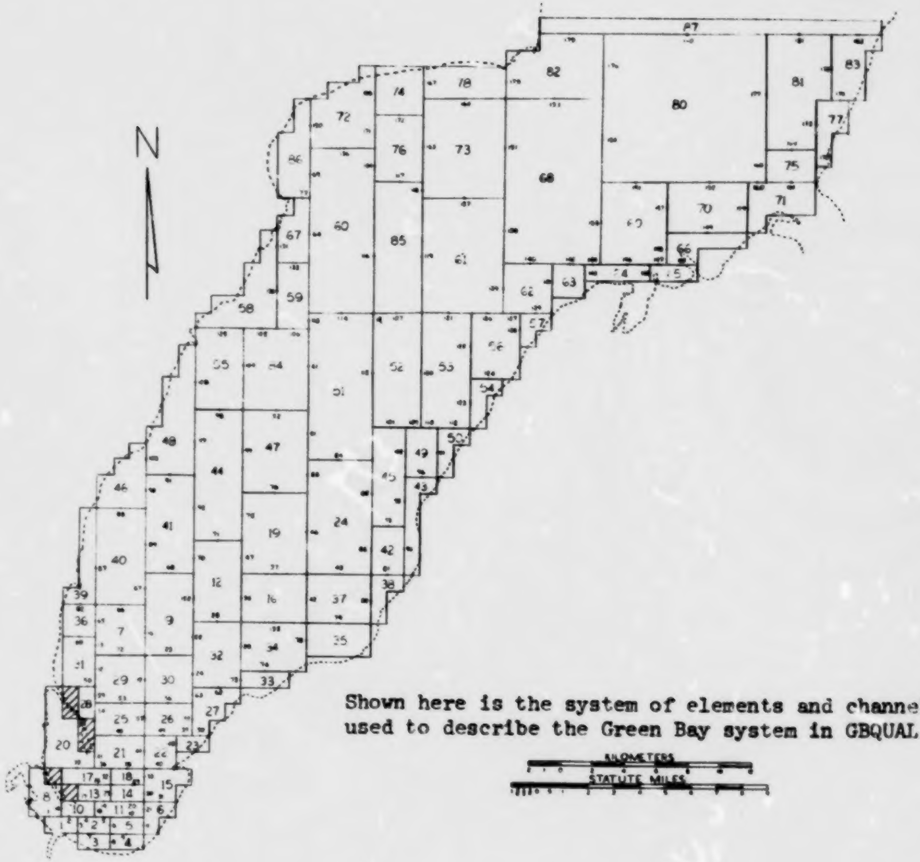
A network of interconnecting channels (links) and junctions (nodes) is used to describe the physical system. The junctions each describe an element of water (of varying size and shape) which is assumed to be well mixed. All reactions take place inside the junctions. The size and shape of the junctions are chosen to coincide with the geometry of the system being represented. Secondly, the size (volume) of the junctions must be chosen so that a reasonable time step may be used in the model consistent with channel lengths and velocities.

The numerical model performs a mass balance on each constituent plus and minus any sources or sinks of that constituent for each junction or water volume in the Bay. A total of 87 nodes are used to describe the system. This is shown in Figure D-1. Each element or node is described by its surface area, average depth and total volume. Each node is also connected to the surrounding nodes by a series of channels. The channels are described by average depth, flow length and surface area. In addition to the physical data used to describe each node and channel, the program requires a list of all channels entering each node (a maximum of 8) and the nodes connected by each channel (maximum of 2). The flow of water in each channel therefore describes the advection of water for a given simulation run. Water is also allowed to diffuse between nodes by means of an eddy diffusion coefficient that is variable by channel.

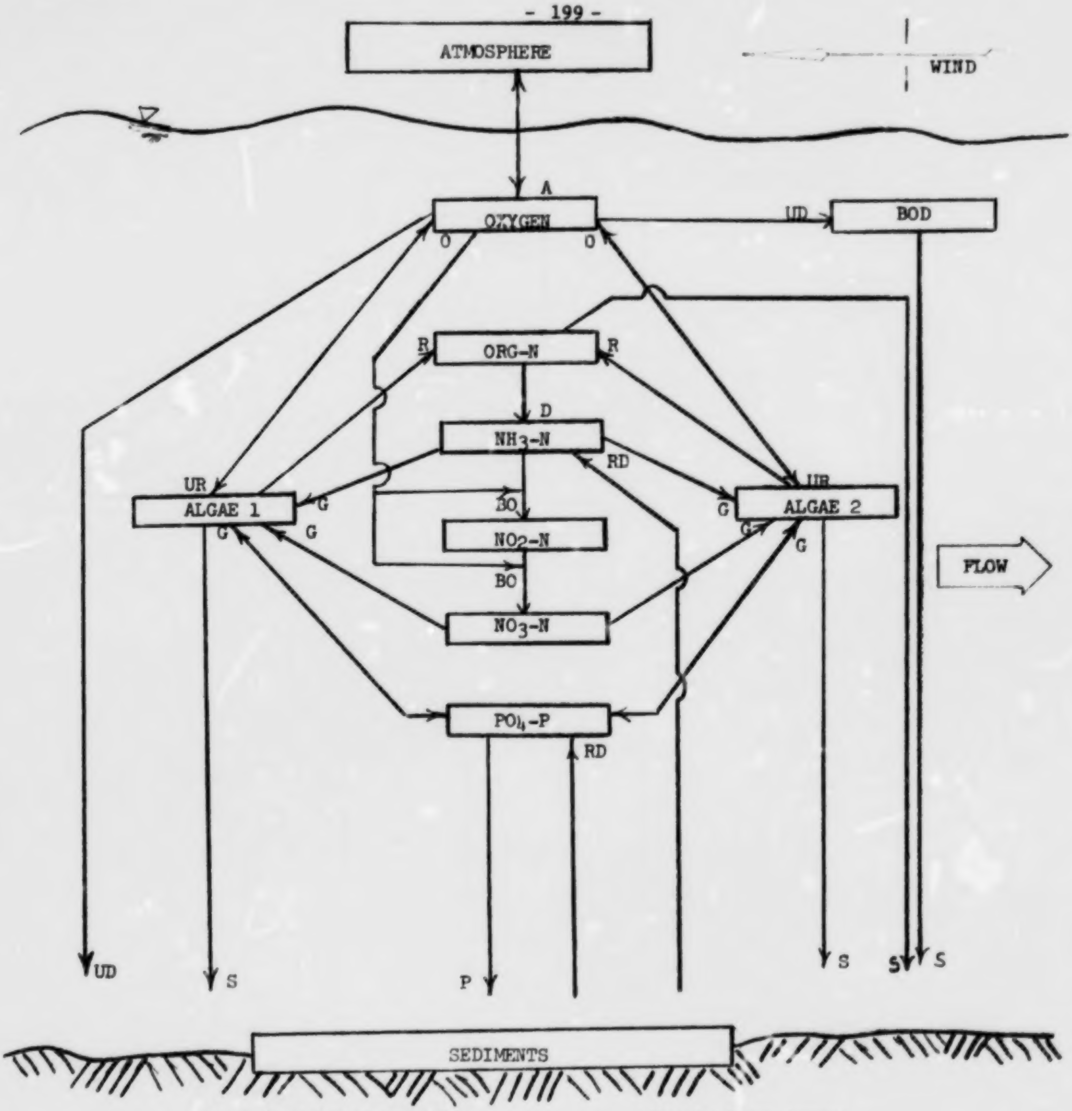
Figure D-2 illustrates the possible chemical and biological reactions that the model considers. (Temperature and coliforms are not shown). These reactions are carried out in each node at each time step. The numerical model assumes that an element is continuously mixed and all reactions take place within the element after advection, diffusion, inflows and outflows have been accounted for. Figure D-3 illustrates the principle of a continuously mixed element.

Program DYNQUA is the master control program and it also contains the main water quality routing loop. As the program executes, control is passed from DYNQUA to INDATA through which all necessary data required for a given simulation is pulled into the program and printed for display. INDATA calls two separate subroutines (COEFF and METDAT) which are designed to read in separate blocks of data. After all necessary data has been read, control passes back to DYNQUA where various system parameters are initialized. The main quality loop is then entered and the program cycles for the designated number of iterations.

FIGURE D-1


N
KILOMETERS
STATUTE MILES

Shown here is the system of elements and channels used to describe the Green Bay system in GBQUAL.


ATMOSPHERE
WIND
A
OXYGEN
O
O
UD
BOD
R
ORG-N
R
D
NH3-N
RD
UR
ALGAE 1
G
G
G
BO
NO2-N
BO
UR
G
ALGAE 2
G
G
FLOW
NO3-N
PO4-P
RD
UD
S
P
S
S
S
SEDIMENTS

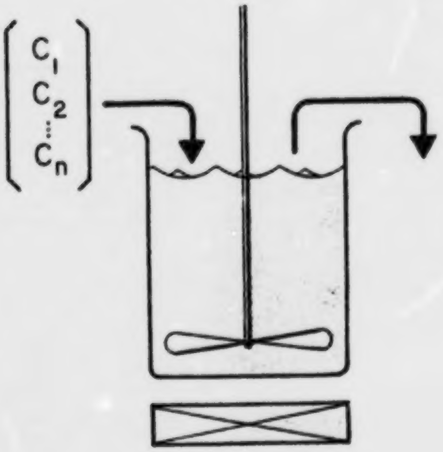
A - Aeration-Deaeration
BO - Oxidation
D - Decay
O - Oxygenation During Algae Growth
UR - Uptake From Respiration
UD - Uptake From Decay

G - Uptake From Growth
R - Resolubilized During Respiration
RD - Resolubilized During Decay
S - Settling
P - Precipitation

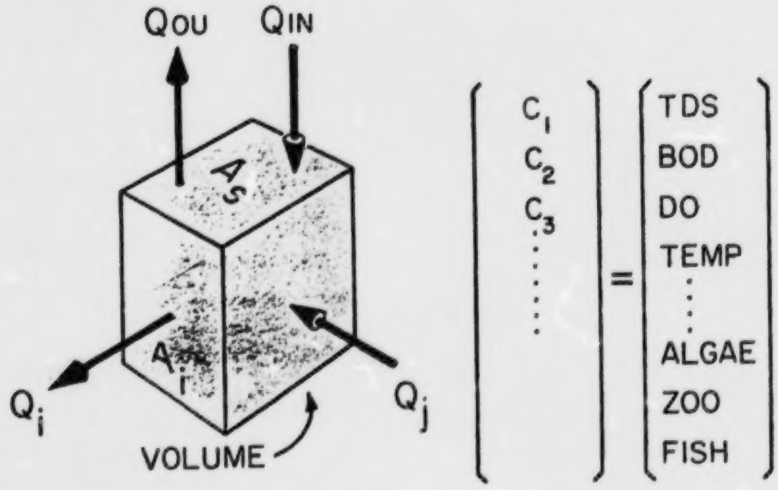
FIGURE D-2

Chemical and Biological Paths Allowed in GBQUAL

FIGURE D-3



A. *a continuously stirred tank reactor, CSTR*


QOU
QIN
A_S
A_i
Q_i
Q_j
VOLUME
C_1
C_2
C_3
=
TDS
BOD
DO
TEMP
ALGAE
ZOO
FISH

B. *an idealized hydraulic element*

A CONTINUOUSLY STIRRED TANK REACTOR (CSTR)
AND AN IDEALIZED HYDRAULIC ELEMENT

(After Water Resources Engineers, Inc.)

If temperature is being simulated, each quality cycle (time step) will include a call to TEMPER (an entry point in METDAT) where the heat budget is calculated and new temperatures are determined. After the proper number of cycles have been completed, a full or partial print out of the current system status is made. If desired the system constituent status is stored for later use in subroutine QUALEX. After the requested number of cycles, a second report is generated by QUALEX giving the minimum, maximum and average concentration of each constituent during the number of cycles requested. After all cycles have been completed, DYNQUA can transfer the current system status to a storage tape or file so that the system can be restarted with the same conditions that it ended with during the last simulation run. Thus the final conditions become the new initial conditions. In this manner, it is possible to route the model through any simulation period (say a year) in a piece-wise fashion without having to reinitialize for each run. Figure D-4 illustrates the informational flow in the program as described above.

GBQUAL has certain limits that are necessitated by the size and speed of present day computers. Table D-1 lists the present dimensional limits of the model along with constituents allowed. If a user wishes to extend these limits, the common blocks in the program will have to be extended. Of course, there is a trade off in the resolution of the physical system and the length of any computational time step. Care must be taken to avoid advecting a significant fraction of any elements volume during a single time step since this may lead to instabilities in the solution. The hydrodynamics for a given simulation run must be steady state over the simulation period. The program can be restarted, however, with a new hydrodynamic solution at any user defined interval if varying flow conditions are desired. With the present set-up for Green Bay, time steps of 3 to 6 hours

FIGURE D-4
FUNCTIONAL DATA FLOW IN PROGRAM GBQUAL

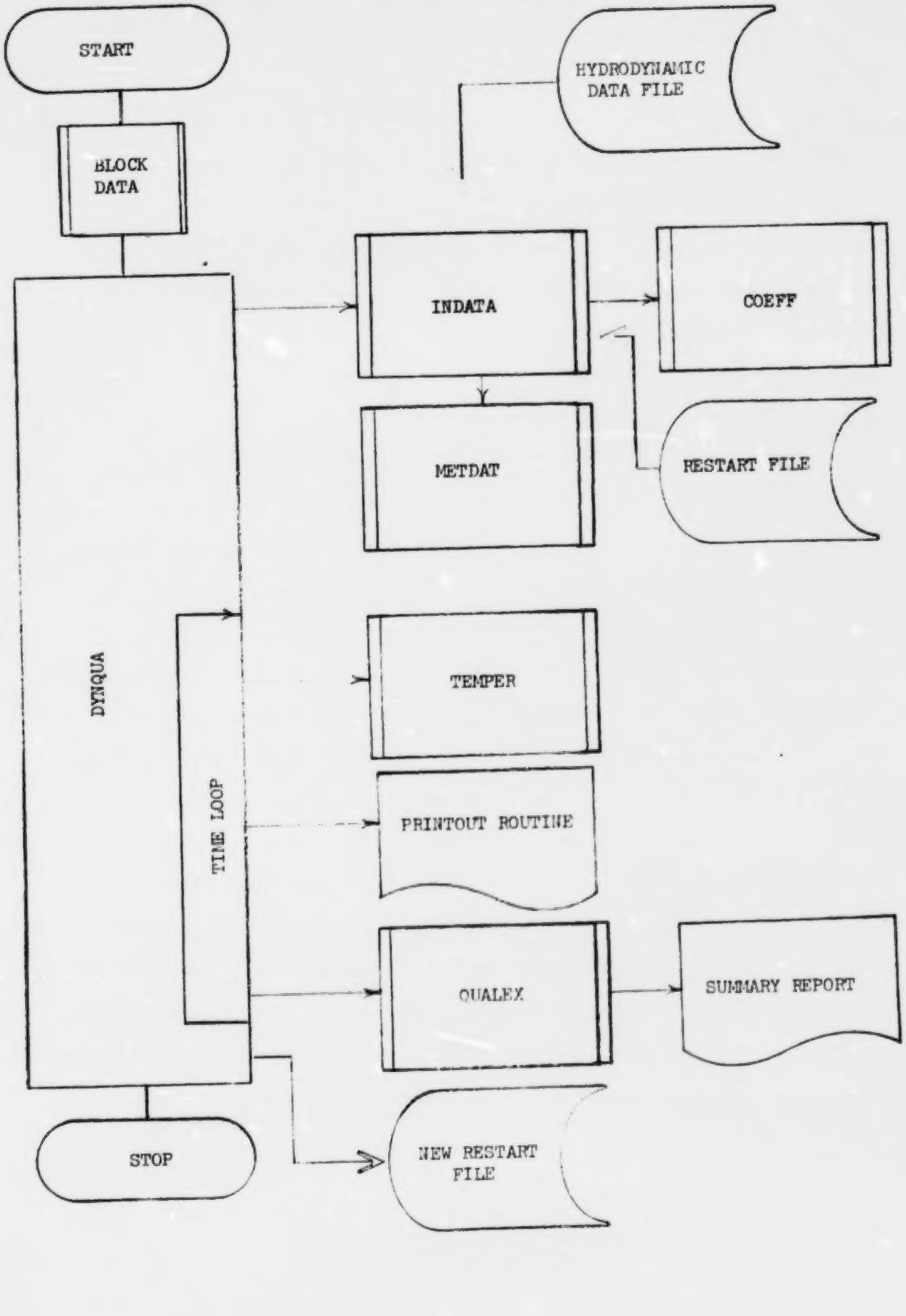

START
BLOCK DATA
HYDRODYNAMIC DATA FILE
INDATA
COEFF
METDAT
RESTART FILE
DYNQUA
TIME LOOP
TEMPER
PRINTOUT ROUTINE
QUALEX
SUMMARY REPORT
STOP
NEW RESTART FILE

TABLE D-1

GBQUAL Limitations and Routable Constituents

Quality Program:

Item	Maximum Number
Junctions	200
Channels	400
Channels Per Junction	8
Water Quality Constituents	14
Wastewater Return Units	20
Quality Multiplication Factors	10
Junctions for Printout	200
Weather Data Points (per day)	25

Constituents that can be modelled are:

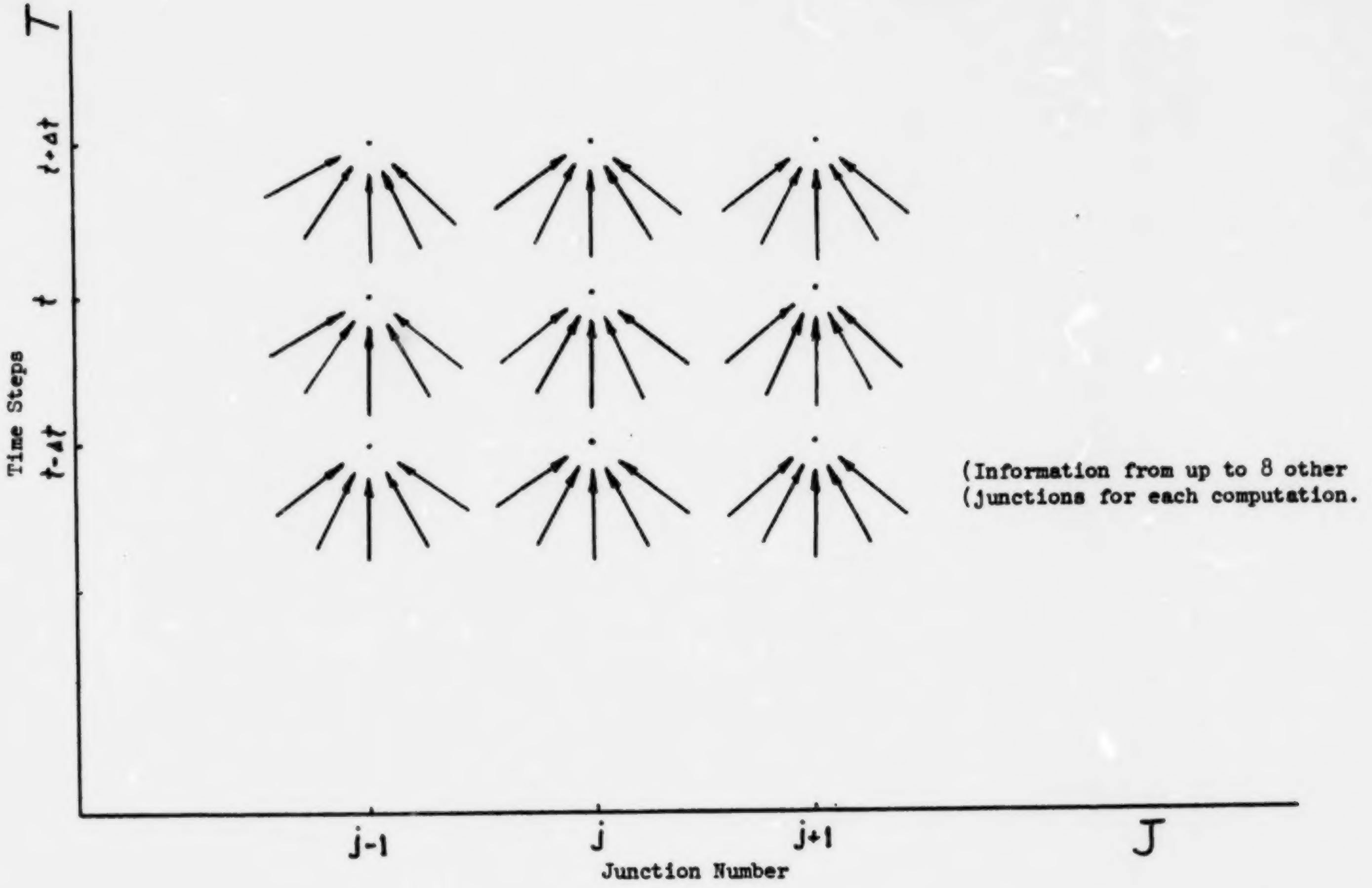
Constituent	Constituent
1	Temperature, ^{o}C
2	Dissolved Oxygen, mg/l
3,4,5	Biochemical Oxygen Demand, mg/l
6	Organic Nitrogen, mg/l
7	Ammonia Nitrogen, mg/l
8	Nitrite Nitrogen, mg/l
9	Nitrate Nitrogen, mg/l
10	Phosphate phosphorus, mg/l
11	Chlorophyll-a(1) ug/l
12	Chlorophyll-a(2) ug/l
13	Coliforms, MPN/100 ml
14	Total Nitrogen, mg/l

seem reasonable. The computer code which was run on an Univac 1110 computer requires approximately 60K words of core for an execution. With a 6 hour time step, a run simulating all parameters for 75 days of actual time requires about 2 1/4 minutes of computer time. Therefore GBQUAL can simulate an extended real-time in a very acceptable amount of computational time.

It should be noted that GBQUAL solves for the concentration of each constituent in a step wise fashion through time. Thus the concentration in any element at time t is a function of the concentration at $(t - \Delta t)$ and all reactions during Δt. This is illustrated in Figure D-5. The solution is therefore an explicit algorithm.

FIGURE D-5

Solution of the Green Bay Model Differential Equations in T and J Space


T
t+Δt
t
t-Δt
Time Steps
j-1
j
j+1
J
Junction Number

(Information from up to 8 other
(junctions for each computation.

Theoretical Considerations of the Water Quality Model

Conservation of mass must be applied at all node points in the numeric scheme. To account for this conservation, whether it be the water itself or a particular constituent, we must look at all inflows and outflows. These consist of advection, diffusion, any external inflow (such as a waste source) or any external withdrawal (such as a water supply system). If we apply these conditions to a given element j we find:

$$V_j C_j^+ = \underbrace{V_{oj} C_j}_{\text{Initial}} + \underbrace{\sum_{i=1}^{n} A_{xi} U_i C^* \Delta t}_{\text{Advection}} + \underbrace{\sum_{i=1}^{n} K_{df} A_{xi} \frac{\Delta C}{xi} \Delta t}_{\text{Diffusion}} \tag{1}$$

$$+ \underbrace{\sum_{in=1}^{nin} Q_{in} C_{in} \Delta t}_{\text{Inflow}} - \underbrace{\sum_{oi=1}^{noi} Q_{oi} C_j \Delta t}_{\text{Outflow}}$$

where: V_j = volume of j at the end of a time step

V_{oj} = volume of j at the beginning of a time step

C_j^+ = concentration of C at the end of a time step

C_j = initial concentration

n = number of channels into j

A_{xi} = area of channel i

U_i = velocity in channel i

C^* = 1/4 point concentration of C in channel i

Δt = time step

K_{df} = diffusion coefficient

$\frac{\Delta c}{xi}$ = concentration gradient

X_i = channel length

Q_{in} = inflow

Q_{oi} = outflow

C_{in} = concentration of C in the inflow nin = number of inflows

noi = number of outflows

This balance accounts for the physical transport of any constituient between nodes. The mass balance equation is the most important equation in the system. Equation D-1 requires that a balance between all inflows and outflows must occur at all nodes. If this condition were not true, the model would be "creating or losing mass" which is not physically possible. Thus care must be taken that this condition be met at all points in the system.

In addition to this balance, the internal chemical and biological reactions must be considered. Exchanges between the sediment and water interface or the air water interfaces must also be accounted for. Figure D-2 illustrates the basic paths that the various constituents simulated may follow. This conceptualization is obviously a simplification of a real system and yet it allows one to mathematically describe the major reactions that affect the system. As our understanding of the phenomena involved increases we will undoubtably refine our conceptual diagrams and also the mathematical descriptions of them.

The next sections will describe the mathematical formulas used in the Green Bay Water Quality Model. Most of these reactions have been seen before, however, some new considerations have been included and will be elaborated on. A summary of all differential equations solved in GBQUAL is shown in Table D-2.

TABLE D-2

Summary of Differential Equations Solved by the GBQUAL Model

Description	Equation										
		Advection	Diffusion	Inflow	Outflow	Decay	Sedimentation	Respiration Or Release	Transformation	Chemical or Biological Uptake	Heat Exchange or Reaeration
QUALITY PROGRAM:											
Conservative Constituent (TDS, T. Nitrogen)(c):	$\frac{\partial VC}{\partial t}$	$= \sum_{i=1}^{I} (A_x uC)_i$	$+ \sum_{i=1}^{I} (A_x K \frac{\partial C}{d\partial x})_i$	$+ \sum_{j=1}^{J} (Q_{in} C_{in})_j$	$- \sum_{j=1}^{J} (Q_{ou} C)_j$	(i = channels; j = inflows or outflows per junction)					
Temperature (T):	$\frac{\partial VT}{\partial t}$	$= \sum_{i=1}^{I} (A_x uT)_i$	$+ \sum_{i=1}^{I} (A_x K \frac{\partial T}{d\partial x})_i$	$+ \sum_{j=1}^{J} (Q_{in} T_{in})_j$	$- \sum_{j=1}^{J} (Q_{ou} C)_j$						$+ \frac{A_S Q_H}{\rho_w C_p}$
Coliform Bacteria (F):	$\frac{\partial VF}{\partial t}$	$= \Big[\sum_{i=1}^{I} (A_x uF)_i$	$+ \sum_{i=1}^{I} (A_x K \frac{\partial F}{d\partial x})_i$	$+ \sum_{j=1}^{J} (Q_{in} F_{in})_j$	$- \sum_{j=1}^{J} (Q_{ou} F)_j \Big]$	$(1 - \beta_5)$					
Ammonia Nitrogen (N_1):	$\frac{\partial VN_1}{\partial t}$	$= \Big[\sum_{i=1}^{I} (A_x uN_1)_i$	$+ \sum_{i=1}^{I} (A_x K \frac{\partial N_1}{d\partial x})_i$	$+ \sum_{j=1}^{J} (Q_{in} N_1)_j$	$- \sum_{j=1}^{J} (Q_{ou} N_1)_j \Big]$	$(1 - \beta_1)$		$+ A_s \sigma_1 R_B^{(T-20)}$	$+ VN_o(1 - \beta_5)$	$- VA\,\alpha_1 F_2$	
Nitrite Nitrogen (N_2):	$\frac{\partial VN_2}{\partial t}$	$= \Big[\sum_{i=1}^{I} (A_x uN_2)_i$	$+ \sum_{i=1}^{I} (A_x K \frac{\partial N_2}{d\partial x})_i$	$+ \sum_{j=1}^{J} (Q_{in} N_2)_j$	$- \sum_{j=1}^{J} (Q_{ou} N_2)_j \Big]$	$(1 - \beta_2)$			$+ VN_1(1 - \beta_1)$		
Nitrate Nitrogen (N_3):	$\frac{\partial VN_3}{\partial t}$	$= \sum_{i=1}^{I} (A_x uN_3)_i$	$+ \sum_{i=1}^{I} (A_x K \frac{\partial N_3}{d\partial x})_i$	$+ \sum_{j=1}^{J} (Q_{in} N_3)_j$	$- \sum_{j=1}^{J} (Q_{ou} N_3) J$				$+ VN_2(1 - \beta_2)$	$- VA\mu\alpha_1 F_1$	
Phosphate Phosphorus (P):	$\frac{\partial VP}{\partial t}$	$= \Big[\sum_{i=1}^{I} (A_x uP)_i$	$+ \sum_{i=1}^{I} (A_x K \frac{\partial P}{d\partial x})_i$	$+ \sum_{j=1}^{J} (Q_{in} P)_j$	$- \sum_{j=1}^{J} (Q_{ou} P)_j \Big]$		$(1 - S_2)$	$+ A_S \sigma_2 R_B^{(T-20)}$		$- VA\alpha_2(\mu - \rho)$	
Algae (A):	$\frac{\partial VA}{\partial t}$	$= \sum_{i=1}^{I} (A_x uA)_i$	$+ \sum_{i=1}^{I} (A_x K \frac{\partial A}{d\partial x})_i$	$+ \sum_{j=1}^{J} (Q_{in} A)_j$	$- \sum_{j=1}^{J} (Q_{ou} A)_j$					$+ VA(\mu - \rho - \sigma_1)$	
Organic Nitrogen:	$\frac{\partial VN_o}{\partial t}$	$= \Big[\sum_{i=1}^{I} (A_x uN_o)_i$	$+ \sum_{i=1}^{I} (A_x K \frac{\partial N_o}{d\partial x})_i$	$+ \sum_{j=1}^{J} (Q_{in} N_o)_j$	$- \sum_{j=1}^{J} (Q_{ou} N_o)_j \Big]$	$(1 - \beta_6)$				$+ VA\rho\alpha_1$	

TABLE D-2 (continued)

Description	Equation									
	Advection	Diffusion	Inflow	Outflow	Decay	Sedimentation	Respiration Or Release	Transformation	Chemical or Biological Uptake	Heat Exchange or Reaeration
Dissolved Oxygen (O):	$\frac{\partial VO}{\partial t} = \sum_{i=1}^{I} (A_x uO)_i$	$+ \sum_{i=1}^{I} (A_x K_d \frac{\partial O}{\partial x})_i$	$+ \sum_{j=1}^{J} (Q_{in}O)_j$	$- \sum_{j=1}^{J} (Q_{ou}O)_j$	$-VB(1-\beta_4)$	$- A_S K_B R_B^{(T-20)}$	$+ VA(\alpha_5 \mu - \alpha_6 \rho)$	$- VN_1(1-\beta_2)\alpha_7$	$- VN_2(1-\beta_2)\alpha_8$	$+ A_S K_R(O^* - O)$
Carbonaceous BOD (B):	$\frac{\partial VB}{\partial t} = \Big[\sum_{i=1}^{I} (A_x uB)_u$	$+ \sum_{i=1}^{I} (A_x K_d \frac{\partial B}{\partial x})_i$	$+ \sum_{j=1}^{J} (Q_{in}B)_j$	$- \sum_{j=1}^{J} (Q_{ou}B)_j$	$\Big](1-\beta_4)$					
Rate coefficient time and temperature changes:	$\beta_{1,2,3,4,5} = R^{(T-20)}_{N_3,N_2,E,D,F} e^{-\Delta t k_{3,4,6,7,1,5}}$ $\mu = R_A^{(T-20)} (e^{-K_8 \Delta t} - 1)$ $\beta_9 = R_A^{(T-20)} (1 - e^{-K_9 \Delta t})$				$F_1 = \frac{N_3}{N_1 + N_3}$ $F_2 = \frac{N_1}{N_1 + N_3}$					

Phytoplankton

GBQUAL has the capability of routing two seperate algae populations. The growth of both groups of algae are considered to follow Monod kinetics. The limiting factors considered are phosphate concentration, inorganic nitrogen concentration, light availability and temperature. The mathematical formula is given by:

$$\mu = \mu_{MAX} \left[\theta^{T-20}\right] X \left[\frac{PO_4\text{-}P}{P_{SP} + PO_4\text{-}P}\right] X \left[\frac{NO_3\text{-}N + NH_3\text{-}N}{P_{SN} + NO_3\text{-}N + NH_3\text{-}N}\right] r \tag{2}$$

where: μ_{MAX} = maximum growth at 20° C

θ = temperature correction coefficient

T = temperature °C

$$\left.\begin{array}{l} PO_4\text{-}P \\ NO_3\text{-}N \\ NH_3\text{-}N \end{array}\right\} \text{concentrations}$$

P_{SP} = half saturation constant for phosphate

P_{SN} = half saturation constant for inorganic nitrogen

r = fraction of the maximum growth rate as a result of light intensity

All of the above terms have been discussed in past literature except the term r. The factor r is a function of light penetration, depth of the water, and a normalized growth function for light intensity. Figure D-6 presents a diagram from the EPA publication *Dynamic Water Quality Forecasting and Management* (O'Connor, Thomann, Ditoro, 1973). This series of graphs illustrates the normalized growth rate function and its comparison to three sets of observations. To elaborate on this relationship it is necessary to describe the effects of algal populations and the resultant light penetration. Light penetration is normally described by an extinction coefficient. Various equations have been developed to account for changes in the extinction coefficient as a result of changes in the algal density. One such equation is shown below.

$$k_E = k_{OE} + .00268\ (\text{CHL-a}) + .01645\ (\text{CHL-a})^{2/3} \qquad (3)$$

where: k_E = actual extinction coefficient (1/ft)

k_{OE} = extinction coefficient as a result of things other than algal

CHL-a = total concentration of Chl-a in ug/l

This formulation contributes a "self-shading" effect to dense algal populations. A concentration of 100 ug/l of Chl-a (frequently observed in Lower Green Bay) will contribute 0.62/ft to the extinction coefficient. Light penetration of between 5 and 10 feet (Secchi Disk) is a typical value if we exclude the algal self-shading. With a conversion of 1.9/(Secchi depth) we would have a range of .38 to .19 for Ke. Thus the self-shading effect of algae in Green Bay may be an important limiting factor in algal growth. The extinction coefficient may increase by 200 to 300% as a result of a dense algae population.

The light intensity at any depth can then be given in terms of Ke as:

$$I(z) = I_o\, e^{-(k_E z)} \qquad (4)$$

where e = base of natural logs
I = intensity
z = depth (positive downward)
I_o = intensity at the surface

Based on the data of Ryther (Figure D-6), Steele has proposed a formulization for the normalized growth of phytoplankton as a function of light. The equation developed by Steele relates the normalized growth rate of algae as a function of light intensity and a saturated light intensity. It is given by:

$$F(I) = \frac{I}{I_s} e^{\left(-\frac{I}{I_s} + 1\right)} \qquad (5)$$

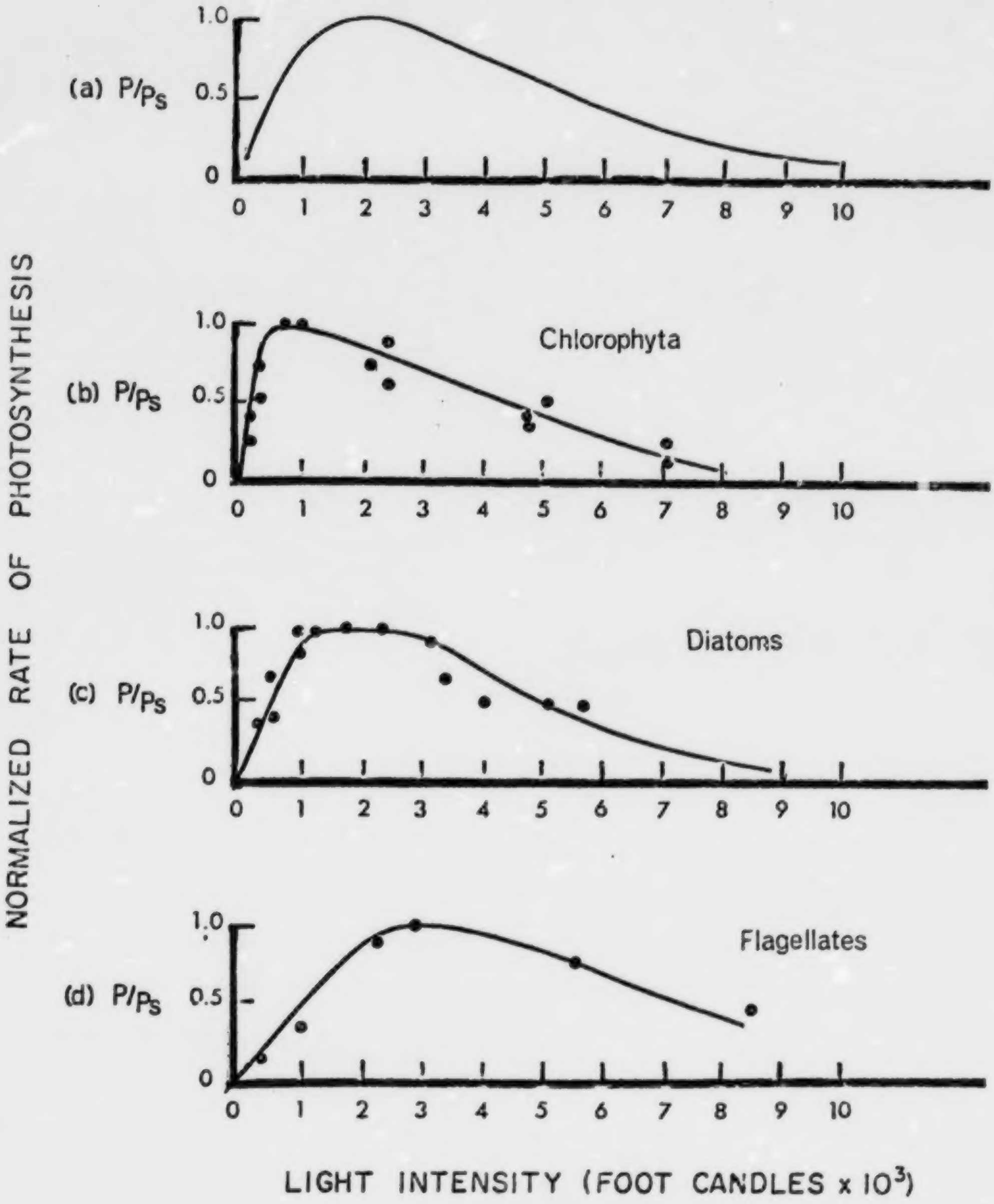
where: F = normalized rate of growth
I = local light intensity
I_s = saturated light intensity

To obtain the average normalized growth rate over a volume element during a given time step, we must integrate this expression over the depth and time step Δt. The intensity of light is, of course, a function of depth as given above and is also a function of the time of day. We can assume that I_o is constant over a given time step if we use a sinusoidal light intensity function with time and evaluate the intensity at half time steps. Then the fractional growth rate r is given by:

$$r = \frac{1}{D} \int_o^D \frac{1}{T} \int_o^f \frac{Iae^{-kEz}}{I_s} e^{\left(- \frac{Iae^{-kEz}}{I_s} + 1\right)} dt\,dz \qquad (6)$$

FIGURE D-6

(Taken from EPA publication 66013-73-009)



Normalized Rate of Photosynthesis vs. Incident Light Intensity: (a) Theoretical Curve after Steele (b,c,d) Data after Ryther where: D = depth

T = hours in Δt

f = hours of daylight in Δt

I_a = average light intensity at the surface over Δt

We can integrate this formulization to obtain:

$$r = \frac{ef}{Tk_E D} (e^{-A1} - e^{-Ao}) \qquad (7)$$

where:

$$A_1 = \frac{I_a}{I_s} e^{-k_E D}$$

$$A_o = \frac{I_a}{I_s}$$

Now it remains to determine a reasonable range of values for Is. Steele's formula was based on 2000 footcandles as being the average saturated growth intensity. However, most measurements of sunlight are given in terms of langleys (g cal/cm^2) which is an energy term. The conversion from footcandles to langley depends on the frequency of light you are considering. For the visible spectrum it appears that Is will be in the range of 0.05 to 0.15 langleys per minute. Water Resources Engineering has suggested a half saturation constant for light as .03 langleys/minute. If we set F(I) equal to 0.5 and Ia to 0.03 and solve for Is we obtain a value of 0.13 langley per minute.

The death of phytoplankton is considered to be dependent on temperature only. The death rate is given by:

$$\rho = \theta^{T-20} (1 - e^{-\rho_{20} \Delta t}) \qquad (8)$$

where: ρ = local death rate

ρ_{20} = death rate at 20°C.

Phytoplankton can also leave the water system by settling to the bottom. Normally a settling rate of between .5 and 2.0 ft/day is appropriate. The mass balance of algae applied to any element j then looks like:

$$VA_j^{+} = VA + V_j A_j \, (\overset{\text{Growth}}{\mu_j} \quad - \quad \overset{\text{Death}}{\rho_j} \quad - \quad \overset{\text{Settling}}{\sigma_j}) \qquad (9)$$

where: A_j^{+} = algae biomass after Δt

VA = mass balance from equation 1

σ_j = settling rate in ft/DAY/DEPTH

Nutrient Cycles

The nutrients considered in GBQUAL consist of 4 forms of nitrogen and soluble phosphate. Nitrogen is allowed to transform from organic compounds to ammonia and then to either be utilized by plankton or to nitrify. Nitrate is also utilized by plankton. In addition, ammonia may be released from decaying organics in the sediments. To complete the cycle, nitrogen associated with plankton can either leave the system by settling or resolubilize as free organic compounds. It is important to realize that the organic nitrogen routed by the model refers only to the free organic N not bound up in algae.

Phosphate can be released from sediments, precipitate to the sediments, or be utilized by algae. The cycle is again completed by resolubilization from respired algae or settling to the bottom out of the system.

Nitrogen Kinetics

Organic nitrogen is assumed to decompose to ammonia via a first order reaction. The differential equation for the reaction takes the form:

$$\frac{dN_o}{dt} = \alpha_{12}\,\rho\,A - \alpha_{11}\,N_o \qquad (10)$$

where: N_o = Org. -N concentration

α_{12} = fraction of algae that is nitrogen

α_{11} = rate constant (1/day) for Org-N to NH_3-N

The other terms have previously been defined. The rate constant α_{11} is assumed to vary with temperature.

Ammonia nitrogen decays to NO_2-N thru a first order reaction. It is also generated from bottom muds or by Org-N decomposition and it is used by algae. The equation is:

$$\frac{dN_1}{dt} = \alpha_{11}\,N_o + \gamma_1\,(A_s) - \beta_1 N_1 - \alpha_{12}\,\mu A N_1 \left(\frac{N_1}{N_1 + N_3}\right)$$

where: N_1 = ammonia nitrogen

γ_1 = release of NH_3-N by sediments per surface area per time

A_s = surface area

β_1 = rate of nitrification of NH_3-N (temperature dependent)

$\frac{N_1}{N_1 + N_3}$ = fraction of nitrogen used by algae that is NH_3-N

Nitrite nitrogen is allowed to decay to nitrate only. The only source (other than inflows) is the end result of NH_3-N decay. The reactions again are first order:

$$\frac{dN_2}{dt} = \beta_1 N_1 - \beta_2 N_2 \tag{12}$$

where: N_2 = nitrite nitrogen

β_2 = rate of NO_2-N to NO_3-N

Nitrate nitrogen can only be utilized by algae or created by nitrite decay. No other sources or sinks are accounted for aside from inflow and outflow. The equation is:

$$\frac{dN_3}{dt} = \beta_2 N_2 - \alpha_{12} u A N_3 \left(\frac{N_3}{N_1 + N_3} \right) \tag{13}$$

where: N_3 = nitrate nitrogen

$\frac{N_3}{N_1 + N_3}$ = fraction of algae nitrogen that comes from nitrate

A possible addition to the model at this point would be the inclusion of a denitrification term that would allow NO_3-N to leave the system (as N_2 gas) under low dissolved oxygen conditions. This would insert an additional nonlinearity.

Phosphate (soluble) is allowed to be both used and released by algae. In addition, phosphate is precipitated to and released from the sediments. The equation takes the form:

$$\frac{dP}{dt} = \alpha_3 (\rho - u) A - \sigma_2 + \gamma_2 (As) \qquad (14)$$

where: ρ = phosphate phosphorus
α_3 = fraction of algae biomass that is phosphorous
σ_2 = rate of phosphorus precipitation to the sediment
γ_2 = release rate of phosphorus per area per time
As = area

Coliform Bacteria

Coliforms are assumed to decay by a first order reaction that is temperature dependent.

$$\frac{dC}{dt} = - kcC \qquad (15)$$

where: C = coliform (MPN)
c = decay rate

Carbonaceous BOD

The BOD in the system is represented by an equation consisting of 3 parallel terms. This equation is given by:

$$L = L_1 (1 - e^{-k_{11}t}) + L_2 (1 - e^{-k_{12}t}) + L_3 (1 - e^{-k_{13}t}) \quad (16)$$

where L = BOD mg/1

L_1, L_2, L_3 = ultimate BOD for each term

k_{11}, k_{12}, k_{13} = first order decay rate 1/day base e

This equation describes a long term BOD curve that consists of three separate terms that are exerted simultaneously. The total ultimate BOD represented by equation 16 is the sum of L_1, L_2, and L_3. If L_2 and L_3 are zero then equation 16 reduces to the classical BOD equation. (See discussion of Long Term BOD in Section IV-C).

The decay of BOD can be represented by the equation:

$$\frac{dL}{dt} = -\sum_{i=1}^{3} k_{1i}L_i \quad (16a)$$

Each term also contributes its oxygen deficit to the total oxygen balance. Of course, when using the ultimate BOD, care must be taken to remove the nitrogenous portion either by inhibiting nitrification during the long term BOD test or measuring the Kjeldahl nitrogen and subtracting its potential oxygen deficit.

Dissolved Oxygen

The concentration of dissolved oxygen is a function of reaeration pressure, net algae production of O_2 and the oxidation of BOD and inorganic nitrogen forms. In addition, oxygen is consumed at the sediment interface as a result of decaying organics. This can be represented by the following equation:

$$\frac{dO}{dt} = k_2 (O_s - O) - \sum_{i=1}^{3} k_{1i} L_i - \beta_1 \alpha_4 N_1 - \beta_2 \alpha_5 N_2 + (r\alpha_6 - \alpha_7) A\alpha_8 - \gamma_3 (As) \tag{17}$$

where: O = dissolved oxygen

O_s = saturation at the given temperature

k_2 = reaeration rate (temperature dependent)

α_4 = oxygen required per unit of ammonia oxidized

α_5 = oxygen required per unit of nitrite oxidized

α_6 = O_2 production per unit of Chl-a

α_7 = O_2 respiration per unit of Chl-a

r = algal activity factor previously defined

α_8 = ratio of Chl-a to algal biomass

γ_3 = O_2 uptake from bottom sediments per area per time

A = algal biomass

Equation 17 is straightforward except for the 5th term which determines the algal contribution. The formulation used here was developed by Ryther and Yentsch and reported by DiToro (1969). The relationship predicted maximum photosynthetic production as a function of Chl-a concentration.

$$P_{MAX} = 0.25\ (CHL - a) = \alpha_6$$

Respiration was given as:

$$R = 0.025\ (CHL - a) = \alpha_7$$

R and P are in terms of mg/l/day and Chl-a is in terms of ug/l. The conversion factors of 0.25 and 0.025 are based on averages over many types of species and may vary considerably in specific cases. Also the 10 to 1 ratio of production to respiration may not always be true. Accordingly, these factors are entered as variables in GBQUAL and may be specified by the user.

Total Nitrogen

Total Nitrogen is routed through the system as a conservative substance. In fact any conservative substance (such as chlorides) could be routed with this routine, however, the name TOTAL NITROGEN will appear in the computer print outs. This was done only for convenience since total nitrogen is the most frequently routed substance by this routine.

A complete listing of various coefficient and parameter values appears in Table D-3.

TABLE D-3

Parameter	Estimated Parameter Values		
	Value Range	Units	Reliability
Decay Rates, Per Day Base E			
BOD-1	0.1 - 0.5	Day^{-1}	Good
BOD-2	0.01 - 0.1	Day^{-1}	Good
BOD-3	0.001- 0.5	Day^{-1}	Good
Org-N	0.01 - 0.01	Day^{-1}	Fair
NH_3-N	0.01 - 0.2	Day^{-1}	Good
NO_2-N	0.2 - 2.0	Day^{-1}	Good
Coliform	0.1 - 3.0	Day^{-1}	Fair
Growth Rates			
ALGAE-1	0.5 - 3.0	Day^{-1}	Fair
ALGAE-2	0.5 - 3.0	Day^{-1}	Fair
Respiration Rates			
ALGAE-1	0.01 - 0.1	Day^{-1}	Fair
ALGAE-2	0.05 - 0.5	Day^{-1}	Fair
Half-Saturation Constants			
ALGAE-1			
(NH_3-N + NO_3-N)	0.02 - 0.4	mg/l	Good
PO_4-P	0.005- 0.05	mg/l	Fair
Light (saturation constant)	5.0 -10.0	langley/hr	Fair
ALGAE-2 - Blue Green N Fixers			
NH_3-N + NO_3-N)	0.0001 (a small value is required to avoid a zerp divide)		
PO_4-P	0.005- 0.05	mg/l	Fair
Light (saturation constant)	5.0 -10.0	langley/hr	Fair
Stoichemetric Equivalence			
$O_2 \rightarrow NH_3$	3.5	mg/mg	Very Good
$O_2 \rightarrow NO_2$	1.2	mg/mg	Very Good
CHL-a (algae 1) $\rightarrow O_2$	.25	ug/mg	Fair
CHL-a (algae 2) $\rightarrow O_2$	.25	ug/mg	Fair

Temperature Coefficients $\theta = a_1 + a_2T + a_3T^2$

	a_1	a_2	a_3	Reliability
BOD-1	1.140098	-0.003856	0.0	Good
BOD-2	1.140098	-0.003856	0.0	Good
BOD-3	1.140098	-0.003856	0.0	Good
Org-N	1.047	0.0	0.0	Fair
NH_3-N	1.2134705	-0.0107843	0.0	Fair
NO_2-N	1.2134705	-0.0107843	0.0	Fair
Coliforms	1.047	0.0	0.0	--
ALGAE-1 Growth	1.047	0.0	0.0	Fair
ALGAE-2 Growth	1.047	0.0	0.0	Fair
Sediment Oxygen	1.100	-0.00175	0.0	Fair

Miscellaneous

Ratio CHL-A 1/ALGAE-1 Biomass	0.025-0.10	mg/mg	Fair
Ratio CHL-A 2/ALGAE-2 Biomass	0.025-0.10	mg/mg	Fair

Program Documentation

This section presents the logical flow chart for the main program and each subroutine in GBQUAL. This is followed by a complete listing of each subroutine.

Main Program DYNQUA

This routine is the master control routine for GBQUAL and contains all the necessary equations to route all constituents except temperature. This routine calls in all data, cycles through the main quality loop and creates a printed report at desired intervals. The flow chart is illustrated in Figure D-7 and is followed by the listing. The system is controlled by a set of flags called ISWTCH(I). These values are read in INDATA and determine if a given constituent is to be calculated. Table D-4 lists the ISWTCH control values. In addition to the ISWTCH array there are several other internal flags that determine printing times and summary intervals.

Table D-4

ISWTCH(I) flags. Set ISWTCH(I) equal to 1 to simulate a constituent group and set to 0 to skip.

I	Constituents
1	Coliforms
2	Org-N, NH_3-N, NO_2-N, NO_3-N, PO_4-P, CHL-a-1
3	CHL-a-2
4	Total Nitrogen (or any conservative)
5	BOD and DO
6	Temperature

FIGURE D-7
FLOW CHART FOR DYNQUA

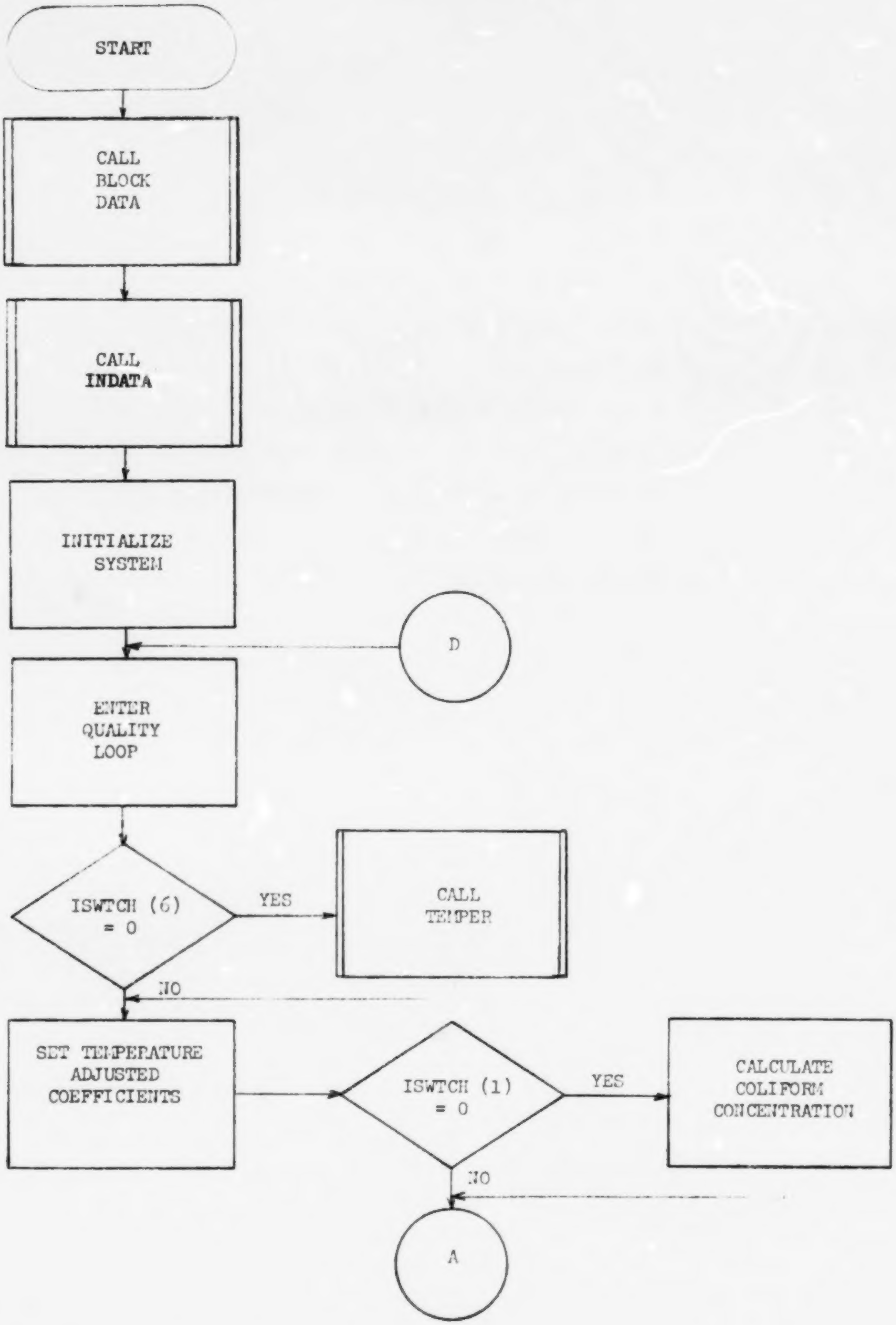

START
CALL
BLOCK
DATA
CALL
INDATA
INITIALIZE
SYSTEM
D
ENTER
QUALITY
LOOP
ISWTCH (6)
= 0
YES
CALL
TEMPER
NO
SET TEMPERATURE
ADJUSTED
COEFFICIENTS
ISWTCH (1)
= 0
YES
CALCULATE
COLIFORM
CONCENTRATION
NO
A

FIGURE D-7
DYNQUA FLOW CHART (CONTINUED)

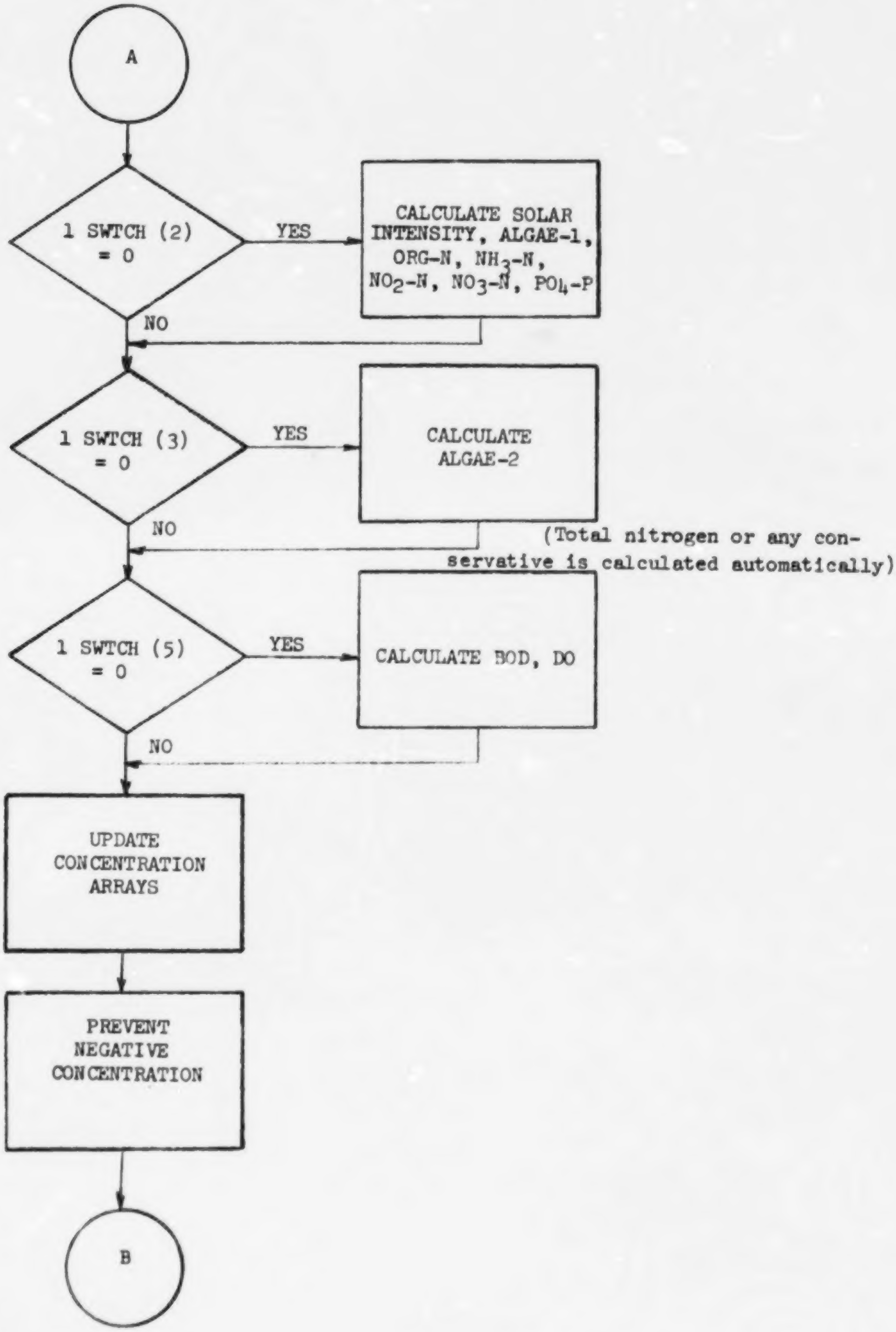

A
1 SWTCH (2) = 0
YES
CALCULATE SOLAR INTENSITY, ALGAE-1, ORG-N, NH_3-N, NO_2-N, NO_3-N, PO_4-P
NO
1 SWTCH (3) = 0
YES
CALCULATE ALGAE-2
NO
(Total nitrogen or any conservative is calculated automatically)
1 SWTCH (5) = 0
YES
CALCULATE BOD, DO
NO
UPDATE CONCENTRATION ARRAYS
PREVENT NEGATIVE CONCENTRATION
B

FIGURE D-7
(Continued)

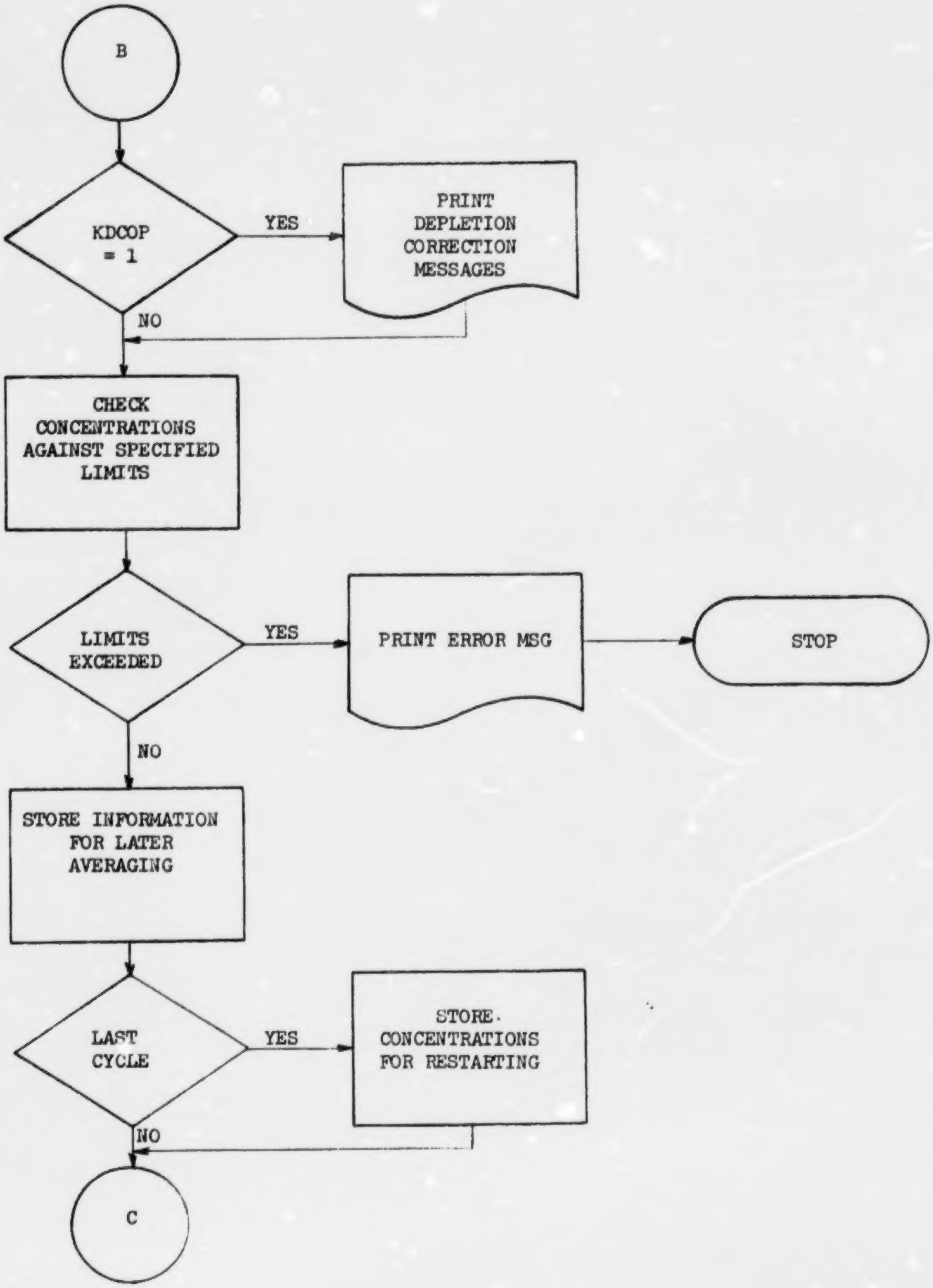
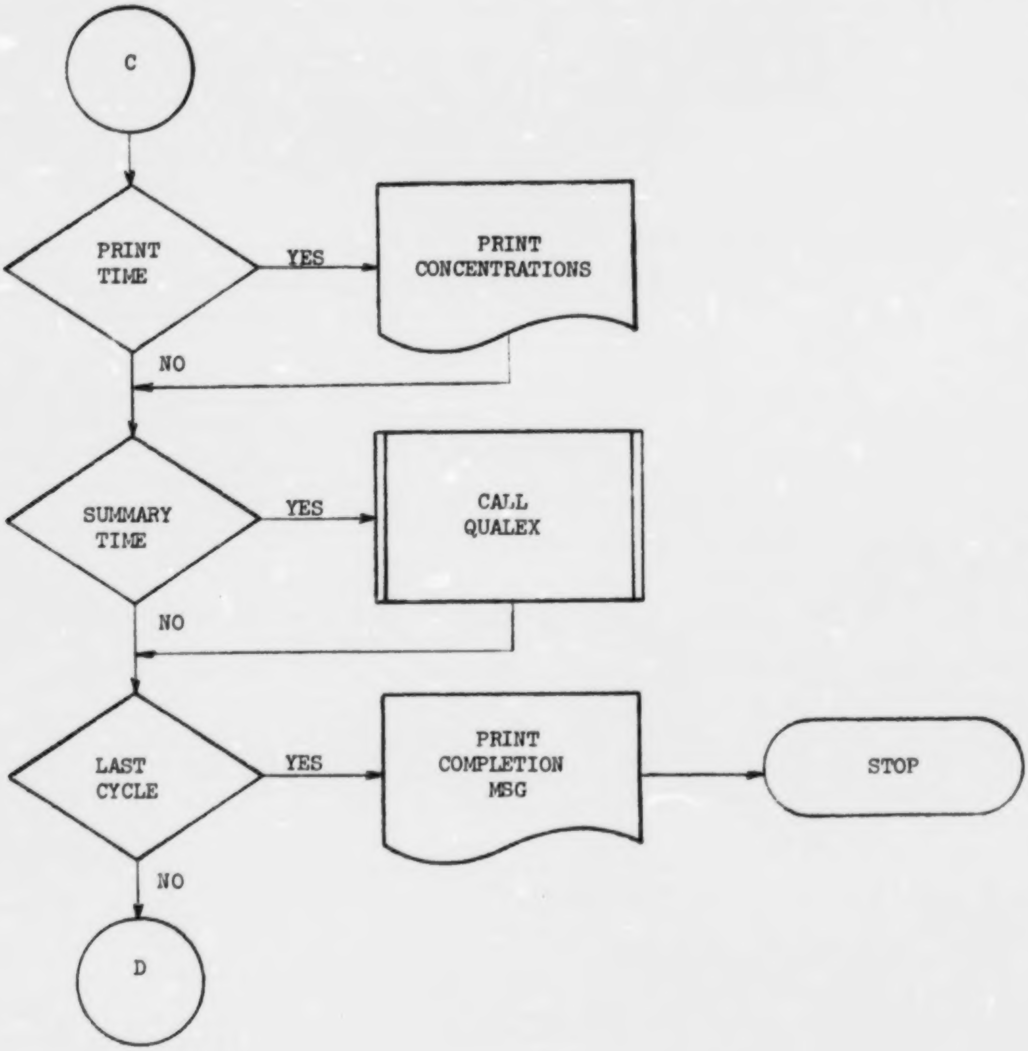

B
KDCOP
= 1
YES
PRINT
DEPLETION
CORRECTION
MESSAGES
NO
CHECK
CONCENTRATIONS
AGAINST SPECIFIED
LIMITS
LIMITS
EXCEEDED
YES
PRINT ERROR MSG
STOP
NO
STORE INFORMATION
FOR LATER
AVERAGING
LAST
CYCLE
YES
STORE
CONCENTRATIONS
FOR RESTARTING
NO
C

FIGURE D-7
(Continued)


C
PRINT TIME
YES
PRINT CONCENTRATIONS
NO
SUMMARY TIME
YES
CALL QUALEX
NO
LAST CYCLE
YES
PRINT COMPLETION MSG
STOP
NO
D

```
C                              PROGRAM DYNQUA
C
C
C                   ENVIRONMENTAL PROTECTION AGENCY
C                DYNAMIC ESTUARY AND TIDAL TEMPERATURE MODEL
C                   WRE  15 CONSTITUENT ECOLOGIC VERSION
C
C*****************************************************************
C
C        THE PROGRAM LOGIC IN THIS DECK WAS ORIGINALLY DEVELOPED FOR THE
C        NETWORKS REPRESENTING THE SAN FRANCISCO BAY-DELTA AND THE
C        SAN DIEGO BAY SYSTEMS.  ITS PRESENT FORM, A MODIFICATION DEVELOPED
C        FOR PEARL HARBOR, INCLUDES CAPABILITY TO SIMULATE 14 CONSTITUENTS
C        AND THEIR INTERACTIONS IN A VERTICALLY MIXED CLOSED BAY OR
C        ESTUARY.  THE QUALITY CONDITIONS AT THE SEAWARD BOUNDARY MUST
C        BE SPECIFIED.  APPLICATION TO OTHER SYSTEMS MAY REQUIRE
C        SOME PROGRAM MODIFICATIONS.
C
C*****************************************************************
C
      COMMON/GEOM/YNEW(200),VOLQIN(200),VOL(200),ASUR(200),QIN(200),
     1           NCHAN(200,8),DIFFK(400),V(400),Q(400),AREA(400),
     2           B(400),CLEN(400),R(400),CN(400),NJUNC(400,2)
     3          ,QNET(200),Y(200),QOUT(200),VOLQOU(200)
     4,          YBAR(200),JGW,JS,NC,NJ
      COMMON/MISC/ALPHA(80),CDIFFK,CIN(14,1),CLIMIT(14),CONST(20,14)
     A,      CTEMP(14),DELT,DTQ,EBBCON(48,14),EXR,FACTR(14,10),IEXC
     B,      INCYC,INTDIG,IPRT,ITAPE(5),IWRINT,IWRITE,JDIV1(20),JDIV2(20)
     C,      JPRT(300),JRET1(20),JRET2(20),KBOP(14),KDCOP,KZOP,MM,NEXTPR
     D,      NEXTWR,NGROUP(14),NJSTOP(14,10),NJSTRT(14,10),NODYN,NOPRT
     E,      NQCYC,NQPRT,NRSTRT,NSPEC,NSTOP,NTAG,NUMCON,NUNITS,N10,N20
     F,      N30,N40,RETFAC(20,14),NEX,ISWTCH(10),NAME(20),INAME(5,14)
     G,      DELTQ,KDONE,MARK1,MARK2
C
C
      COMMON/INFL/TEMPIN(200),OXYIN(200),BODIN(200,3),CORGIN(200),
     $           CNH3IN(200),CNO2IN(200),CNO3IN(200),PO4IN(200),
     $           ALGIN1(200),ALGIN2(200),COLIN(200),TNIN(200),
     $           CHA1IN(200),CHA2IN(200)
C
C
      COMMON/CONC/TEMP(200),OXY(200),BOD(200,3),CORG(200),CNH3(200),
     $           CNO2(200),CNO3(200),PO4(200),ALG1(200),ALG2(200),
     $           COL(200),TN(200),CHLA1(200),CHLA2(200)
C
C
      COMMON/MASS/TEMPM(200),OXYM(200),BODM(200,3),CORGM(200),CNH3M(200)
     $           ,CNO2M(200),CNO3M(200),PO4M(200),ALG1M(200),
     $           ALG2M(200),COLM(200),TNM(200),CHLA1M(200),
     $           CHLA2M(200)
C
C
      COMMON/RATE/REOX(200),COLDK(200),BODDK(200,3),CNH3DK(200),
     $           CORGDK(200),EXPBO2(200),AGSNK1(200),AGSNK2(200),
     $           CNO2DK(200),POSINK(200),OXYBEN(200),CNHBEN(200),
     $           SECHI(200),PMAX1(200),PMAX2(200),AGCHA1(200),
     $              AGCHA2(200),PO4BEN(200),PRES1(200),PRES2(200),
     $              DFBIO1(200),DFBOD(200,3),DFCOL(200),DFNH3(200),
     $              DFNO2(200),DFOGN(200),DFBIO2(200),EXPBEN(200),
     $              EXPBO1(200),EXPBOD(200,3),EXPCOL(200),EXPNH3(200),
     $              EXPNO2(200),EXPORG(200),CNBEN(200),CSAT(200),
     $              OXBEN(200),OXDELT(200),POBEN(200),CFBOD,ALGIP,
      COMMON/ATMS/QC(200),QA(200),QE(200),EQTEM(200),XQNS(200),QTOT(200)
     A,     QHS(25,10),QHA(25,10),QRNETA(25,10),UWINDA(25,10),TAA(25,10)
     B,     TAWA(25,10),AFA(25,10),CLOUD(25,10),IEQTEM,JWZONE(10,2)
     C,     QRNET(200),AX(4),BX(4),ALPH(8),BETA(8),PI,W60,DTOR
C
C
      COMMON/ICHECK/JIGNOR(200)
C
      DIMENSION C(200,14),CMASS(200,14),CSPEC(200,14),CT(200)
      EQUIVALENCE (C(1,1),TEMP(1)),(CMASS(1,1),TEMPM(1))
     $            ,(CSPEC(1,1),TEMPIN(1))
C
C
C
      FMA(X,Y,Z)=Z-1.0/Y*ALOG(1.0+X*EXP(Y*Z))
      SATOXY(X,Y)=14.6009-0.3881*X+6.23E-3*X*X-3.0E-5*X*X*X
     1            -Y*(1.665E-4-5.866E-6*X+9.796E-8*X*X)
      DRR(X,Y,Z)=EXP(-X*Z)/EXP(-X*Y)
C
C
      READ(5,*) IIII
C
C..... CALL SUBROUTINE TO READ PROBLEM RELATED DATA
      CALL BLOCK
C
      CALL INDATA
C
C . . . . . . . . . . . . . . . . .  STEP  1
C**** INITIALIZATION
C
      ICYCIF=0.0
      EBBTOT=0.0
      NEBB=0
      KOUNE = 0
      MARK1 = 0
      MARK2 = 0
      DELTQ=DELT*3600.
      NCOUNT = 0
      KOUNTT = 0
      MARK1=IWRITE
      NTEMP=1
      DO 358 N=1,NC
      IF(NJUNC(N,1)-NJUNC(N,2))356,358,357
```

```
  357 KEEP=NJUNC(N,1)
      NJUNC(N,1)=NJUNC(N,2)
      NJUNC(N,2)=KEEP
      Q(N)  =  -Q(N)
  358 CONTINUE
      WRITE(6,356)  (Q(N), N=1,NC)
  356 FORMAT(10F8.1)
      IF(ISATCH(6).EQ.0) GO TO 353
      DO 355 J=JS,NJ
  355 CT(J)=TEMP(J)
  353 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP  2
C..... CALCULATE JUNCTION VOLUMES AT BEGINNING OF SIMULATION PERIOD
C
  776 DO 780 J=1,NJ
      VOL(J)=ASUR(J)*Y(J)
  780 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP  3
C..... CALCULATE INITIAL MASS IN JUNCTIONS
C
      DO 378 J=1,NJ
      DO 377 K=1,NUMCON
      CMASS(J,K)= C(J,K) * VOL(J)
      CHLA1M(J)=CHLA1(J)*VOL(J)
      CHLA2M(J)=CHLA2(J)*VOL(J)
  377 CONTINUE
  378 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP  4
C**** EDDY DIFFUSION CONSTANT
C
C     ORIGINALLY THE EDDY DIFFUSION COEFFICIENT WAS READ IN HERE
C     NOW THE DIFFUSION COEFFICIENTS ARE READ IN IN SUBROUTINE COEFF
C
C . . . . . . . . . . . . . . . . . .  STEP  5
C***** COMPUTE VOLUMES OF INFLOW-OUTFLOW
C
      DO 388 J=1,NJ
      VOLQIN(J)=-QIN(J)*DELTQ
      VOLQOU(J)=QOUT(J)*DELTQ
  388 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP  6
C..... STORE INITIAL CONDITIONS ON EXTRACT (SUMMARY) TAPE
C
C***********************************************************************
C                         BEGIN MAIN QUALITY LOOP
C***********************************************************************
      DO 536 ICYC=INCYC,NQCYC
      NQCYCC = ICYC
C
C . . . . . . . . . . . . . . . . . .  STEP  7
C
C
C . . . . . . . . . . . . . . . . . .  STEP  9
```

```
C***** DETERMINE FLOW DIRECTION AND COMPUTE 1/4 POINT CONCENTRATION
C
      DO 416 N=1,NC
      VOLFLW = Q(N) * DELTQ
      NL = NJUNC(N,1)
      NH = NJUNC(N,2)
C     DX=V(N)*DELTQ
C     F=DX/CLEN(N)
C     IF(F.GT.0.5) F=0.5
      F=0.25
      FACTOR=0.5-F
      IF(Q(N).GE.0.0) FACTOR=0.5+F

  412 DO 414 K=1,NUMCON
      IF(CIN(K,1).LT.-9.E+19) GO TO 414
      QGRAD = C(NL,K) - C(NH,K)
      CONC = C(NH,K) + FACTOR * QGRAD
C
C . . . . . . . . . . . . . . . . . .  STEP 10
C***** ADVECTION AND DIFFUSION
C
      ADMASS = CONC * VOLFLW
      DIMASS = DIFFK(N) * DELTQ * AREA(N) * QGRAD /CLEN(N)
      CMASS(NH,K) = CMASS(NH,K) + ADMASS + DIMASS
      CMASS(NL,K) = CMASS(NL,K) - ADMASS - DIMASS
  414 CONTINUE
  416 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP 11
C..... ADD WASTE DISCHARGE AND DIVERSION MASSES TO THE JUNCTIONS
C
      DO 434 J=JS,NJ
      IF(VOLQIN(J).GE.0.0) GO TO 430
      DO 431 K=1,NUMCON
  431 CMASS(J,K)=CMASS(J,K)-CSPEC(J,K)*VOLQIN(J)
  430 CONTINUE
      IF(VOLQOU(J).LE.0.0) GO TO 434
      DO 433 K=1,NUMCON
  433 CMASS(J,K)=CMASS(J,K)-C(J,K)*VOLQOU(J)
  434 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP 12
C***** APPLY WASTE WATER RETURN FACTORS
C
C
C..........TEMPERATURE
C
      IF(ISWTCH(6).EQ.1) GO TO 592
C
C.....CALL TEMPERATURE SIMULATION ROUTINE FOR CALCULATION OF
C      TEMPERATURES AT THE END OF THE QUALITY TIME STEP
C
      CALL TEMPER(TEMP,TEMPM,VOL,ASUM)
C
C . . . . . . . . . . . . . . . . . .  STEP 13
C..... ASSIGN TEMPERATURE ADJUSTED COEFFICIENTS
C
```

```
  592 CONTINUE
      DO 580 J=JS,NJ
      TEMP(J)=TEMPM(J)/VOL(J)
      IT=TEMP(J)
      IF(ISWTCH(6).EQ.1) IT=CT(J)
      IF(IT.LT.1) IT=1
      IF(IT.GT.50) IT=50
      DFBOD(J,1)=EXPBOD(IT,1)*BODDK(J,1)+1.0
      DFBOD(J,2)=EXPBOD(IT,2)*BODDK(J,2)+1.0
      DFBOD(J,3)=EXPBOD(IT,3)*BODDK(J,3)+1.0
      DFCOL(J)=EXPCOL(IT)*COLDK(J)+1.0
      DFNH3(J)=EXPNH3(IT)*CNH3DK(J)+1.0
      DFNO2(J)=EXPNO2(IT)*CNO2DK(J)+1.0
      DFORG(J)=EXPORG(IT)*CORGDK(J)+1.0
      DFBIO1(J)=EXPBO1(IT)
      DFBIO2(J)=EXPBO2(IT)
      OXBEN(J)=OXYBEN(J)*EXPBEN(IT)*ASUR(J)
      POBEN(J)=PO4BEN(J)*EXPBEN(IT)*ASUR(J)
      CNBEN(J)=CNHBEN(J)*EXPBEN(IT)*ASUR(J)
      OXDELT(J)=0.
  580 CONTINUE
C
C . . . . . . . . . . . . . . . . .  STEP 14
C.......... COLIFORMS
C
      IF(ISWTCH(1).EQ.1) GO TO 560
      DO 562 J=JS,NJ
  562 COLM(J)=COLM(J)*DFCOL(J)
  560 CONTINUE
C
C . . . . . . . . . . . . . . . . .  STEP 15
C.......... NUTRIENTS AND ALGAE
C
      IF(ISWTCH(2).EQ.1) GO TO 610
      HOURS=ICYC*DELT
      IDAYS=HOURS/23.99999
      TIME=HOURS-FLOAT(24*IDAYS)
      IJ=IDAYS+1
      DTIME=TIME-DELT/2.
      SET=SRI(IJ)+HDL(IJ)
      IF(DTIME .LT. SRI(IJ) .OR. DTIME .GT. SET) GO TO 2000
      SOAVE=TL(IJ)/HDL(IJ)
      SONET=SOAVE*(1.-COS(2.*3.141592*(DTIME-SRI(IJ))/HDL(IJ)))
      GO TO 2010
 2000 SONET=0.
 2010 CONTINUE
      DO 600 J=JS,NJ
      ICHECK  =  JIGNOR(J)
      IF(ICHECK.GT.0)   GO TO 600
C
C..... ALGAE GROWTH, RESPIRATION AND SETTLING RATES
C
      PMU1=0.
      PMU2=0.
      FRMAX1=0.
      FRMAX2=0.
      IF(SONET .LE. 0.)  GO TO 602
      XP=PO4(J)/(PSP1+PO4(J))
      XN=(CNH3(J)+CNO3(J))/(PSN1+CNH3(J)+CNO3(J))
      CHA=(ALG1(J)*AGCHA1(J)+ALG2(J)*AGCHA2(J))*1000.
      EXCO=SECHI(J)+.00268*CHA+.01645*CHA**.667
      SOLAVE=-SONET/Y(J)/EXCO*(EXP(-EXCO*Y(J))-1.)
      A0=SOLAVE/PSL1
      A1=A0*EXP(-EXCO*Y(J))
      FRMAX1=(2.718282/(EXCO*Y(J)))*(EXP(-A1)-EXP(-A0))
      PMU1=PMAX1(J)*DFBIO1(J)*XP*XN*FRMAX1
  602 CONTINUE
      PR1=PRES1(J)*DFBIO1(J)
      PS1=AGSNK1(J)/Y(J)
C
C.....ALGAE  2
C
      IF(ISWTCH(3) .EQ. 1) GO TO 2020
      PMU2=0.
      IF(SONET .LE. 0.) GO TO 2040
      A0=SOLAVE/PSL2
      A1=A0*EXP(-EXCO*Y(J))
      FRMAX2=(2.718282/(EXCO*Y(J)))*(EXP(-A1)-EXP(-A0))
      XP=PO4(J)/(PSP2+PO4(J))
      XN=(CNH3(J)+CNO3(J))/(PSN2+CNH3(J)+CNO3(J))
      PMU2=PMAX2(J)*DFBIO2(J)*XP*XN*FRMAX2
 2040 CONTINUE
      PR2=PRES2(J)*DFBIO2(J)
      PS2=AGSNK2(J)/Y(J)
 2020 CONTINUE
C
C..... NITRATE NITROGEN
C
      FRAC=CNO3(J)+CNH3(J)
      IF(FRAC .LT. .00001) GO TO 3000
      F1=CNO3(J)/FRAC
      F2=CNH3(J)/FRAC
      GO TO 3010
 3000 F1=.5
      F2=.5
 3010 CONTINUE
C
C
      CNO3M(J)=CNO3M(J)+CNO2M(J)*(1.-DFNO2(J))-ALG1N*PMU1*F1*
     1  ALG1M(J)-ALG2N*PMU2*F1*ALG2M(J)
C
C..... NITRITE NITROGEN
C
      OXDELT(J)=OXDELT(J)-CNO2M(J)*(1.-DFNO2(J))*OXNO2
      CNO2M(J)=CNO2M(J)*DFNO2(J)+CNH3M(J)*(1.-DFNH3(J))
C
C..... AMMONIA NITROGEN
C
      OXDELT(J)=OXDELT(J)-CNH3M(J)*(1.-DFNH3(J))*OXNH3
      CNH3M(J)=CNH3M(J)*DFNH3(J)+CORGM(J)*(1.-DFOGN(J))+
     1  CNBEN(J)-ALG1N*PMU1*F2*ALG1M(J)-ALG2N*PMU2*F2*ALG2M(J)
C
C......ORGANIC NITROGEN (OTHER THAN IN ALGAE)
C
```

```
      CORGM(J)=CORGM(J)*DFOGN(J)+ALG1M(J)*PR1*ALG1N+
     1  ALG2M(J)*PR2*ALG2N
C
C..... PHOSPHORUS
C
      PO4M(J)=PO4M(J)*(1.-POSINK(J))+POBEN(J)-(PMU1-PR1)*ALG1P*
     1  ALG1M(J)-(PMU2-PR2)*ALG2P*ALG2M(J)
C
C..... ALGAE CONCENTRATION AT THE END OF QUALITY STEP
C
      OXDELT(J)=OXDELT(J)+((FRMAX1*OXFAC1-PR1*OXRES1)*CHLA1M(J)+
     1  (FRMAX2*OXFAC2-PR2*OXRES2)*CHLA2M(J))*1000.
      ALG1M(J)=ALG1M(J)*(1.+(PMU1-PR1-PS1))
      ALG2M(J)=ALG2M(J)*(1.+(PMU2-PR2-PS2))
      IF(ALG1M(J) .LT. 0.) ALG1M(J)=0.
      IF(ALG2M(J) .LT. 0.) ALG2M(J)=0.
      CHLA1M(J)=ALG1M(J)*AGCHA1(J)
      CHLA2M(J)=ALG2M(J)*AGCHA2(J)
  600 CONTINUE
  610 CONTINUE
C
C
C . . . . . . . . . . . . . . . . .  STEP 18
C.......... BOD AND DISSOLVED OXYGEN
C
      IF(ISWTCH(5).EQ.1) GO TO 640
      DO 632 J=JS,NJ
      ICHECK  =  JIGNOR(J)
      IF(ICHECK.GT.0)   GO TO 632
      TA=SQRT(1.037**(TEMP(J)-20.))*REOX(J)
      CL=0.
      CSAT(J)=SATOXY(TEMP(J),CL)
      OXYM(J)=OXYM(J)+TA*VOL(J)*(CSAT(J)-OXY(J))
     1         -BODM(J,1)*(1.-DFBOD(J,1))
     2         -BODM(J,2)*(1.-DFBOD(J,2))
     3         -BODM(J,3)*(1.-DFBOD(J,3))
     4         -OXBEN(J)+OXDELT(J)
      BODM(J,1)=BODM(J,1)*DFBOD(J,1)
      BODM(J,2)=BODM(J,2)*DFBOD(J,2)
      BODM(J,3)=BODM(J,3)*DFBOD(J,3)
  632 CONTINUE
  640 CONTINUE
C
C . . . . . . . . . . . . . . . . .  STEP 19
C..... UPDATE JUNCTION VOLUME AND FIND NEW CONCENTRATIONS
C
      DO 446 K=1,NUMCON
      IF(CIN(K,1).LT.-9.E+19) GO TO 446
      DO 444 J=JS,NJ
      ICHECK  =  JIGNOR(J)
      IF(ICHECK.GT.0)   GO TO 444
      C(J,K) =CMASS(J,K) / VOL(J)
  444 CONTINUE
  446 CONTINUE
      DO 448 J=1,NJ
      CHLA1(J)=ALG1(J)*AGCHA1(J)*1000.
      CHLA2(J)=ALG2(J)*AGCHA2(J)*1000.
  498 CONTINUE
C
C . . . . . . . . . . . . . . . . . . STEP 20
C***** PREVENT NEGATIVE CONCENTRATION AND SUPERSATURATION
C
      DO 464 K=1,NUMCON
      IF(CIN(K,1).LT.-9.E+19) GO TO 464
      DO 466 J=JS,NJ
      IF(C(J,K).GE.0.0) GO TO 466
      IF(KDCOP.EQ.2) GO TO 462
  458 WRITE(6,460)             J,ICYC,K,C(J,K)
  460 FORMAT(39H DEPLETION CORRECTION MADE AT JUNCTION I3,7H CYCLE I4,
     * 21H FOR CONSTITUENT NO. I1,12H. CONC. WAS F10.2)
  462 C(J,K) = 0.0
      CMASS(J,K)= 0.0
  466 CONTINUE
  464 CONTINUE
      IF(ISWTCH(5).EQ.1) GO TO 476
C
C . . . . . . . . . . . . . . . . . . STEP 21
C***** LIMIT DISSOLVED OXYGEN CONCENTRATION
C
      ORATIO=1.5
      DO 475 J=JS,NJ
      DOMAX=ORATIO*CSAT(J)
      IF(OXY(J).LT.DOMAX) GO TO 475
      IF(KDCOP.EQ.2) GO TO 475
      WRITE(6,474)  ORATIO,J,ICYC
  474 FORMAT(47H0DISSOLVED OXYGEN CONCENTRATION WAS REDUCED TO  ,F4.1,
     $ 29H TIMES SATURATION AT JUNCTION  ,I4,7H, CYCLE  ,I4)
      OXY(J)=DOMAX
      OXYM(J)=DOMAX*VOL(J)
  475 CONTINUE
  476 CONTINUE
C
C . . . . . . . . . . . . . . . . . . STEP 22
C***** CHECK CONCENTRATIONS AGAINST SPECIFIED LIMITS
C
      DO 482 K=1,NUMCON
      IF(CIN(K,1).LT.-9.0E+19) GO TO 1482
      DO 480 J=1,NJ
      ICHECK=JIGNOR(J)
      IF(ICHECK.GT.0)   GO TO 480
      IF(C(J,K) - CLIMIT(K))480,480,477
  477 WRITE(6,478)             K,CLIMIT(K),J,ICYC
  478 FORMAT(34H0CONCENTRATION OF CONSTITUENT NO. I2,8H EXCEEDS,F7.1,
     * 13H IN JUNCTION I3,14H DURING CYCLE I5,25H.   EXECUTION TERMINATE
     *D.)
      DO 479 L=1,NJ
  479 WRITE(6,481) L,(M,C(L,M),M=1,NUMCON)
  481 FORMAT(I8,6(I4,G11.4)/8X,7(I4,G11.4))
      CALL EXIT
  480 CONTINUE
      GO TO 482
 1482 CONTINUE
      DO 1480 J=1,NJ
 1480 C(J,K)=0.0
```

```
  462 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP 23
C..... WRITE JUNCTION QUALITY ON TAPE FOR LATER AVERAGING
C
      IF(N10 .EQ. 0) GO TO 6000
      IF(ICYC .LT. IWRITE)GO TO 6000
      KOUNTT=KOUNTT+1
      WRITE(N10) ICYC,(TEMP(J),OXY(J),BOD(J,1),BOD(J,2),BOD(J,3),CORG(J)
     1,CNH3(J),CNO2(J),CNO3(J),PO4(J),CHLA1(J),CHLA2(J),COL(J),TN(J),
     2 J=JS,NJ)
 6000 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP 24
C***** STORE OR UPDATE FOR RESTARTING
C
      IF(N30.LE.0) GO TO 520
      IF(ICYC.LT.NQCYC) GO TO 520
  512 WRITE(N30) (ALPHA(I),I=1,80)
      WRITE(N30) ((C(J,K),K=1,NUMCON),J=1,NJ)
      WRITE(6,518)              ICYC,ICYCTF,NTAG
  518 FORMAT(1H1///47H RESTART DECK TAPE WAS LAST WRITTEN AFTER CYCLEI5/
     *       50H HYDRAULIC CYCLE ON EXTRACT TAPE FOR RESTARTING = I5/
     *     8H NTAG = I3///)
      REWIND N30
  520 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP 25
C***** PRINT QUALITY OUTPUT
C
      IF(ICYC-IPRT) 424,524,524
  524 IPRT=IPRT+NQPRT
  528 HOURS = DELTQ * FLOAT (ICYC) / 3600.0
      KDAYS = HOURS / 23.99999
      HOURS = HOURS - FLOAT (24 * KDAYS)
      KDAYS=KDAYS+1
      WRITE(6,530) ICYC,KDAYS,HOURS
  530 FORMAT(10X,'SYSTEM STATUS AFTER QUALITY CYCLE',
     1I4,5X,'DAY',I3,'HOUR',F4.1,//,
     2' JUN  TEMP(C)      OXY    UBOD1    UBOD2    UBOD3    ORG-N       N
     3H3      NO2      NO3      PO4   CHLA-1   CHLA-2  COL/MPN    TOT-N'
     4,/,18X,'MG/L     MG/L     MG/L     MG/L     MG/L     MG/L     MG/L
     5     MG/L     MG/L     UG/L     UG/L                  MG/L',//)
      DO 534 I=1,NOPRT,IIII
      J=JPRT(I)
      WRITE(6,532) J,TEMP(J),OXY(J),BOD(J,1),BOD(J,2),BOD(J,3),CORG(J),
     1 CNH3(J),CNO2(J),CNO3(J),PO4(J),CHLA1(J),CHLA2(J),COL(J),TN(J)
  532 FORMAT(1X,I3,,12F9.3,E9.2,F9.3)
  534 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP 26
C..... PRINT HEAT BUDGET INFORMATION AT EACH PRINT INTERVAL IF DESIRED
C
      IF(IEQTEM.EQ.0) GO TO 424
      BTU2=QRNET(J)*1327.29
      WRITE(6,92)
   92 FORMAT( 50H1      RADIATION TERMS AND EQUILIBRIUM TEMPETATURE
     1/120H0(KCAL IMPLIES KILOGRAM-CALORIES PER SQUARE METER PER SECOND,
     2 BTU IMPLIES BTU PER SQUARE FOOT PER HOUR)
     3/126H0   NET RADIATION        INCOMING SOLAR       BACK RADIATION
     4  EVAPORATION              CONDUCTANCE    EQUIL TEMP
     5/1X,5(20H     KCAL       BTU    ),9H    DEG C  /)
      DO 426 I=1,NOPRT
      J=JPRT(I)
      BTU1=QTOT(J)*1327.29
      BTU3=QA(J)*1327.29
      BTU4=QE(J)*1327.29
      BTU5=QC(J)*1327.29
      WRITE(6,90) QTOT(J),BTU1,QRNET(J),BTU2,QA(J),BTU3,QE(J),BTU4,
     $            QC(J),BTU5,EQTEM(J)
   90 FORMAT(11G10.4)
  426 CONTINUE
  424 CONTINUE
C
C..... CALL QUALITY SUMMARY ROUTINE IF DESIRED
      IF(N10 .EQ. 0) GO TO 535
      IF(KOUNTT .EQ. IPRINT) GO TO 5000
      GO TO 535
 5000 MARK2=ICYC
      CALL QUALEX
      KOUNTT=0
      MARK1=ICYC+1
  535 CONTINUE
  536 CONTINUE
C**********************************************************************
C                         END MAIN QUALITY LOOP
C**********************************************************************
C
C..... PUNCH RESTART DECK OF INITIAL QUALITY CONDITIONS AND INFLOWS
C
      IF(N30.EQ.0) GO TO 541
      REWIND N30
  541 CONTINUE
      WRITE(6,542) NQCYCC
  542 FORMAT(32H QUALITY SIMULATION COMPLETED AT  ,I5,8H CYCLES.  )
      IF(N40.EQ.0) CALL EXIT
      END FILE N40
      REWIND N40
      CALL EXIT
      END
```

Subroutine INDATA

This subroutine controls the input of data to the model. It also writes various reports detailing the data used in the program. INDATA calls two other routines that handle particular blocks of data (COEFF and METDAT). If the particular run is the first run in a series, then initial conditions are looked for in the data input. If this is a restart run, initial conditions are pulled in from a seperate restart tape or storage file. The only exception to this is the temperature. Temperature initial conditions are input in the data deck for every run unless it is being simulated. INDATA also allows the user to alter the restart initial conditions by a multiplication factor applied over any group of junctions.

FIGURE D-8
FLOW CHART FOR INDATA

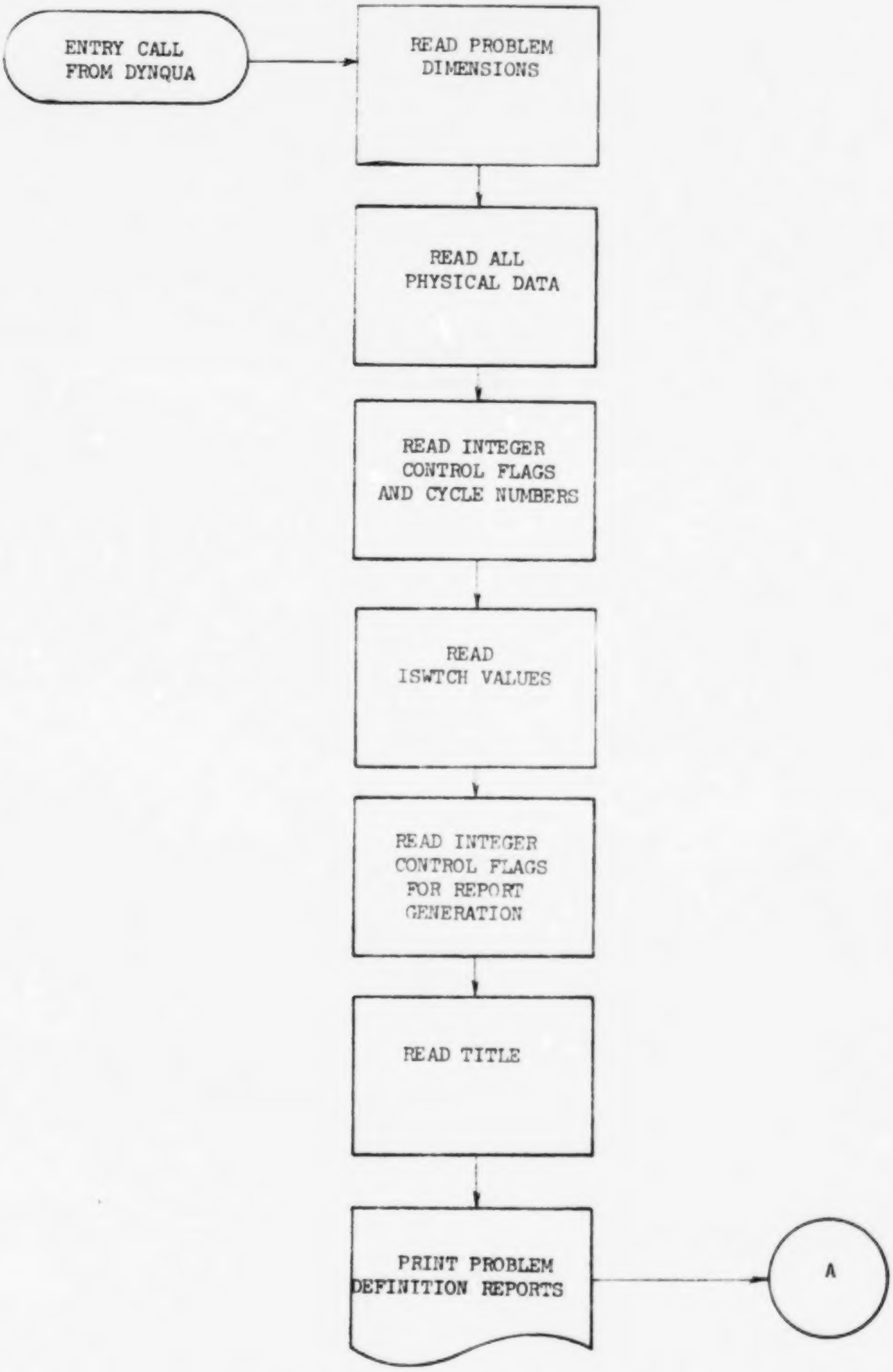

ENTRY CALL FROM DYNQUA
READ PROBLEM DIMENSIONS
READ ALL PHYSICAL DATA
READ INTEGER CONTROL FLAGS AND CYCLE NUMBERS
READ ISWTCH VALUES
READ INTEGER CONTROL FLAGS FOR REPORT GENERATION
READ TITLE
PRINT PROBLEM DEFINITION REPORTS
A

FIGURE D-8
(Continued)

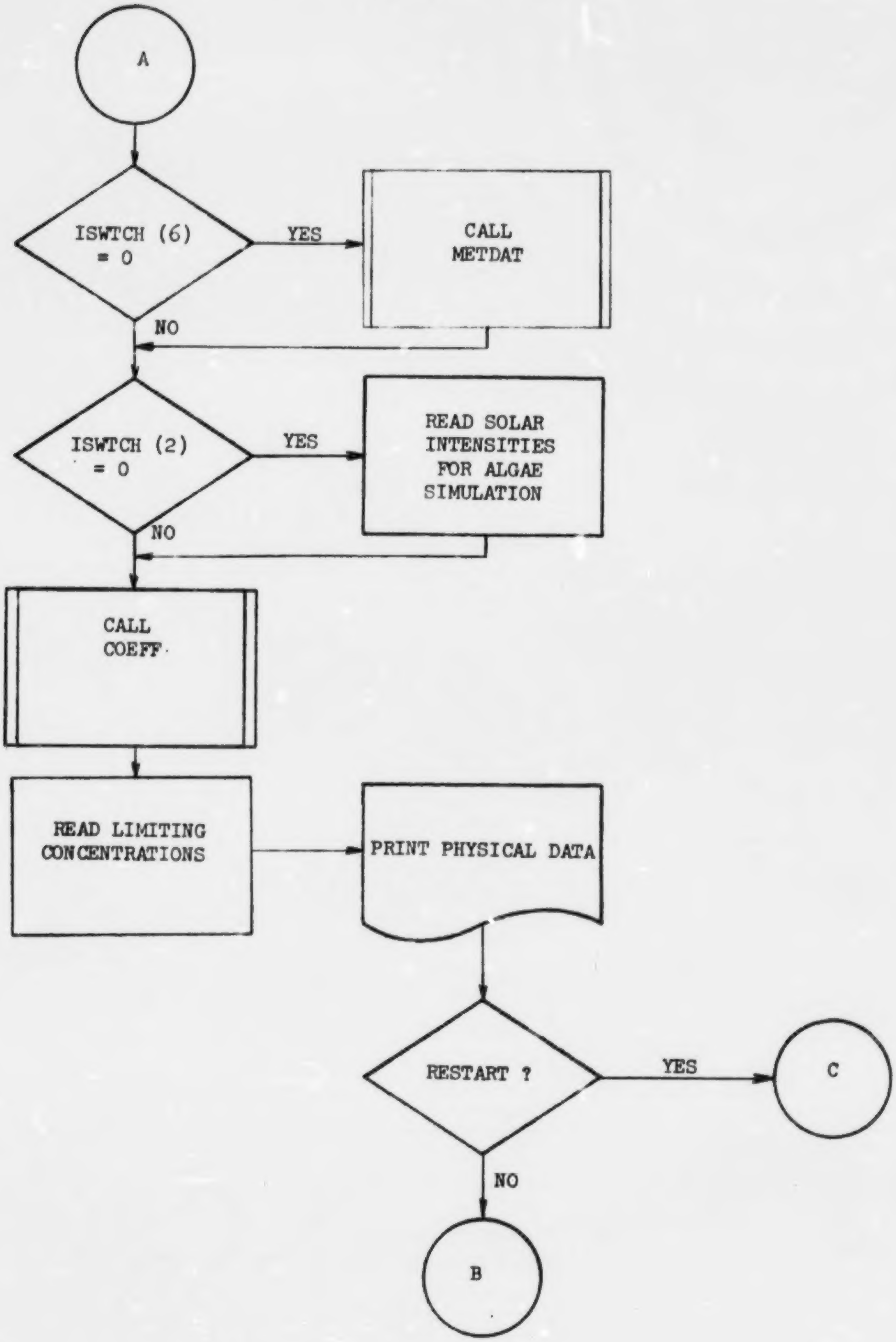
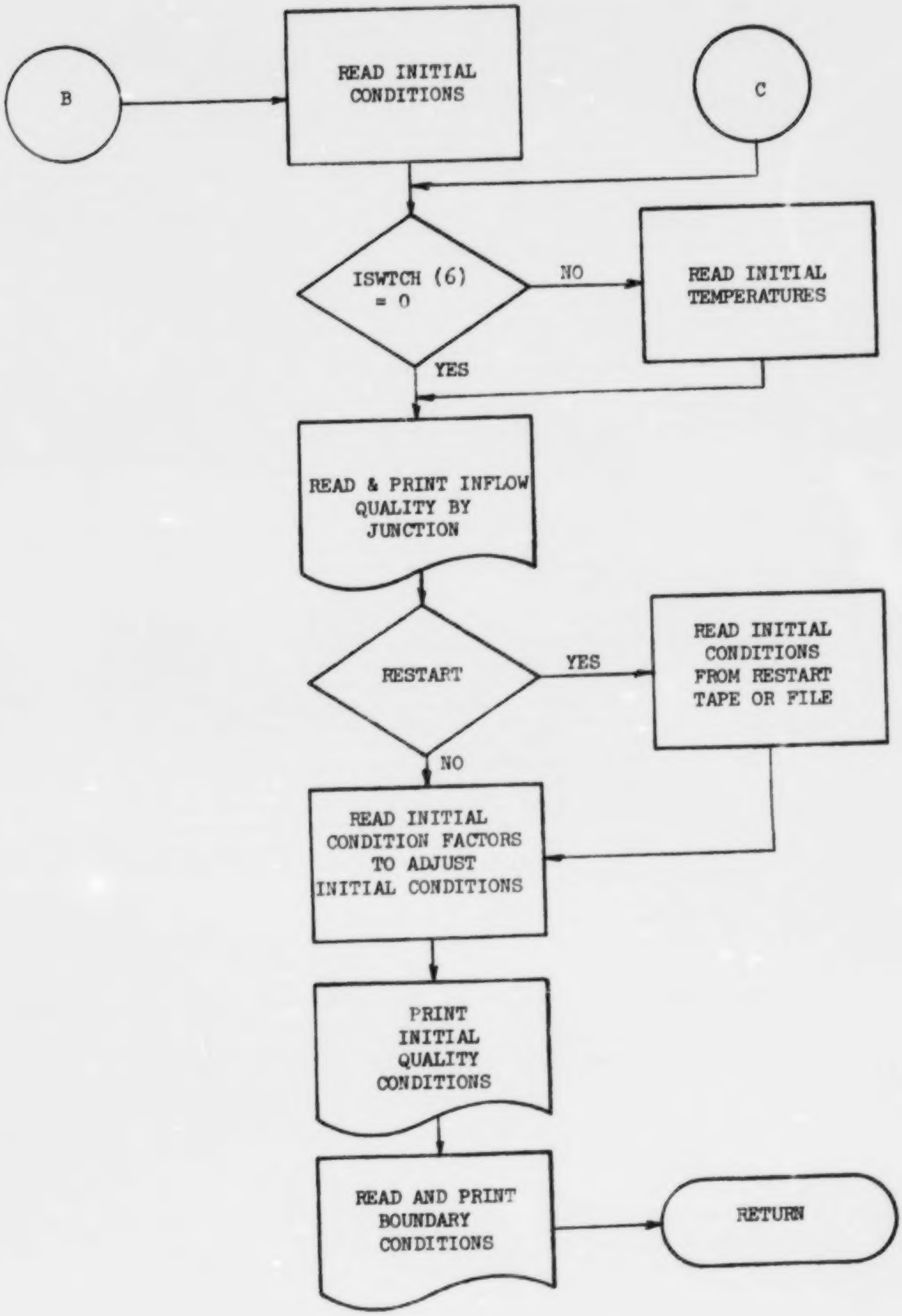

A
ISWTCH (6) = 0
YES
CALL METDAT
NO
ISWTCH (2) = 0
YES
READ SOLAR INTENSITIES FOR ALGAE SIMULATION
NO
CALL COEFF
READ LIMITING CONCENTRATIONS
PRINT PHYSICAL DATA
RESTART ?
YES
C
NO
B

FIGURE D-8
(Continued)



B
READ INITIAL CONDITIONS
C
ISWTCH (6) = 0
NO
READ INITIAL TEMPERATURES
YES
READ & PRINT INFLOW QUALITY BY JUNCTION
RESTART
YES
READ INITIAL CONDITIONS FROM RESTART TAPE OR FILE
NO
READ INITIAL CONDITION FACTORS TO ADJUST INITIAL CONDITIONS
PRINT INITIAL QUALITY CONDITIONS
READ AND PRINT BOUNDARY CONDITIONS
RETURN

```
      SUBROUTINE INDATA
C
      COMMON/GEOM/YNEW(200),VOLQIN(200),VOL(200),ASUR(200),QIN(200),
     1          NCHAN(200,8),DIFFK(400),V(400),Q(400),AREA(400),
     2          B(400),CLEN(400),R(400),CN(400),NJUNC(400,2)
     3         ,QNET(200),Y(200),QOUT(200),VOLQOU(200)
     4,         YBAR(200),JGW,JS,NC,NJ
      COMMON/MISC/ALPHA(80),CDIFFK,CIN(14,1),CLIMIT(14),CONST(20,14)
     A,    CTEMP(14),DELT,DTQ,EBBCON(48,14),EXR,FACTR(14,10),IEXC
     B,    INCYC,INTBIG,IPRT,ITAPE(5),IWRINT,IWRITE,JDIV1(20),JDIV2(20)
     C,    JPRT(300),JRET1(20),JRET2(20),KBOP(14),KDCOP,KZOP,MM,NEXTPR
     D,    NEXTWR,NGROUP(14),NJSTOP(14,10),NJSTRT(14,10),NODYN,NOPRT
     E,    NQCYC,NQPRT,NRSTRT,NSPEC,NSTOP,NTAG,NUMCON,NUNITS,N10,N20
     F,    N30,N40,RETFAC(20,14),NEX,ISWTCH(10),NAME(20),INAME(5,14)
     G,    DELTQ,KDONE,MARK1,MARK2
C
C
      COMMON/INFL/TEMPIN(200),OXYIN(200),BODIN(200,3),CORGIN(200),
     $          CNH3IN(200),CNO2IN(200),CNO3IN(200),PO4IN(200),
     $          ALGIN1(200),ALGIN2(200),COLIN(200),TNIN(200),
     $          CHA1IN(200),CHA2IN(200)
C
C
      COMMON/CONC/TEMP(200),OXY(200),BOD(200,3),CORG(200),CNH3(200),
     $          CNO2(200),CNO3(200),PO4(200),ALG1(200),ALG2(200),
     $          COL(200),TN(200),CHLA1(200),CHLA2(200)
C
C
      COMMON/MASS/TEMPM(200),OXYM(200),BODM(200,3),CORGM(200),CNH3M(200)
     $          ,CNO2M(200),CNO3M(200),PO4M(200),ALG1M(200),
     $          ALG2M(200),COLM(200),TNM(200),CHLA1M(200),
     $          CHLA2M(200)
C
C
      COMMON/RATE/REOX(200),COLDK(200),BODDK(200,3),CNH3DK(200),
     $          CORGDK(200),EXPBO2(200),AGSNK1(200),AGSNK2(200),
     $          CNO2DK(200),POSINK(200),OXYBEN(200),CNHBEN(200),
     $          SECHI(200),PMAX1(200),PMAX2(200),AGCHA1(200),
     $          AGCHA2(200),PO4BEN(200),PRES1(200),PRES2(200),
     $          DFBIO1(200),DFBOD(200,3),DFCOL(200),DFNH3(200),
     $          DFNO2(200),DFOGN(200),DFBIO2(200),EXPBEN(200),
     $          EXPBO1(200),EXPBOD(200,3),EXPCOL(200),EXPNH3(200),
     $          EXPNO2(200),EXPORG(200),CNBEN(200),CSAT(200),
     $          OXBEN(200),OXDELT(200),POBEN(200),CFBOD,ALG1P,
     $          ALG1N,PSP1,PSN1,PSL1,ALG2P,ALG2N,PSP2,PSN2,PSL2,
     $          OXNH3,OXNO2,OXRES1,OXRES2,OXFAC1,OXFAC2,DKBOD,
     $          DKCOL,RACIN,RACEX
C
C
      COMMON/SUN/ TL(365),SRI(365),HDL(365)
C
C
      COMMON/ATMS/QC(200),QW(200),QE(200),EQTEM(200),XQNS(200),QTOT(200)
     A,    QNS(25,10),QNA(25,10),QRNETA(25,10),UWINDA(25,10),TAA(25,10)
     B,    TAWA(25,10),APA(25,10),CLOUD(25,10),IEQTEM,JWZONE(10,2)
     C,    QRNET(200),AX(4),BX(4),ALPH(8),BETA(8),PI,W60,DTOR
```

```
      C
      C
            COMMON/ICHECK/JIGNOR(200)
      C
            DIMENSION JUN1(5),JUN2(5),COEF(5),CT(200)
            DIMENSION C(200,14),CMASS(200,14),CSPEC(200,14)
            EQUIVALENCE (C(1,1),TEMP(1)),(CMASS(1,1),TEMPM(1))
           $             ,(CSPEC(1,1),TEMPIN(1))
      C
      C
      C
      C . . . . . . . . . . . . . . . . . .  STEP  1
      C..... READ CONTROL AND HYDRAULIC DATA
      C
            READ(5,1001) NJ,NC,DELT
       1001 FORMAT(2I5,F10.0)
            READ(5,88)  (JIGNOR(J), J=1,NJ)
         88 FORMAT(40I2)
            READ(5,80) (ITAPE(I),I=1,5)
            DO 82 I=1,4
            N=ITAPE(I)
            IF(N.GT.0) REWIND N
         82 CONTINUE
            N10=ITAPE(1)
            N20=ITAPE(2)
            N30=ITAPE(3)
            N40=ITAPE(4)
         80 FORMAT(16I5)
            MM=1
            READ(5,1002) (ALPHA(I),I=1,80)
       1002 FORMAT(20A4)
            READ(5,*) (  CN(N),N=1,NC)
            READ(5,*) (   R(N),N=1,NC)
            READ(5,*) (   B(N),N=1,NC)
            READ(5,*) (CLEN(N),N=1,NC)
            READ(5,*) ((NJUNC(N,I),I=1,2),N=1,NC)
            READ(5,*) (   Y(J),J=1,NJ)
            READ(5,*) (ASUR(J),J=1,NJ)
            READ(5,*) ((NCHAN(J,K),K=1,8),J=1,NJ)
            DO 9003 N=1,NC
       9003 Q(N)=0.0
            READ(5,*)   (Q(N), N=1,NC)
            DO 9000 N=1,NC
            AREA(N) = B(N)*R(N)
       9000 V(N) = Q(N)/AREA(N)
            ATEN10=10.0**6
            DO 9001 J=1,NJ
       9001 ASUR(J)  =  (ASUR(J)) * ATEN10
      C . . . . . . . . . . . . . . . . . .  STEP  3
      C**** READ INDEPENDENT CONTROL DATA
      C
            READ(5,84)
           $   INCYC,NQCYC,KZOP,KDCOP,NTAG,JS,IEXC
         84 FORMAT(7I5)
            READ(5,40) (ISWTCH(I),I=1,6)
         40 FORMAT(13I5)
            READ(5,80)  IPRT,NQPRT,                 IWRITE,        IWRINT,NOPRT
      READ(5,192)(JPRT(I),I=1,NQPRT)
  192 FORMAT(14I5)
      WRITE(6,105) (ALPHA(I),I=1,60)
  105 FORMAT(     ,4(20X,20A4,/  ))
      DELTQ=DELT*3600.
      DELTQ1=DELT
      DELTQ2=DELTQ1*FLOAT (NQPRT)
      WRITE(6,107)        INCYC,NQCYC,        DELTQ2,DELTQ1
  107 FORMAT(10X,'INITIAL QUALITY CYCLE=',I5,/,
     1     10X,'FINAL QUALITY CYCLE  =',I5,/,
     2     10X,'OUTPUT INTERVAL HOURS=',F10.3,/,
     3     10X,'TIME STEP HOURS      =',F10.3,///)
      WRITE(6,106)(ITAPE(I),I=1,4)
  108 FORMAT(50H THE FOLLOWING TAPE ASSIGNMENTS HAVE BEEN MADE     ,/
     $       45H     INTERNAL SCRATCH FILE                         ,I3,/
     $       45H     HYDRAULIC FILE FROM HYDRAULIC PROGRAM         ,I3,/
     $       45H     RESTART FILE FOR ADDITIONAL SIMULATIONS       ,I3,/
     $       45H     FILE CONTAINING RESTART DATA                  ,I3,///)
      WRITE(6,109) IPRT
  109 FORMAT(31H PRINTOUT IS TO BEGIN AT CYCLE I4//)
      DTD = DELTQ1 / 24.
      NUMCON=14
      IF(JS.LE.0) JS=1
C
C . . . . . . . . . . . . . . . . . .  STEP  4
C..... PRINT CONSTITUENT SELECTED FOR SIMULATION
C
      WRITE(6,120)
  120 FORMAT(        60H THE FOLLOWING CONSTITUENTS ARE BEING CONSIDERED
     $IN THIS RUN        ,/,' CONSTITUENT NO.     CONSTITUENT')
      J=1
      IF(ISWTCH(6).EQ.0) WRITE(6,122) J,(INAME(K,J),K=1,5)
      IF(ISWTCH(5).EQ.1) GO TO 52
      WRITE(6,122) (J,(INAME(K,J),K=1,5),J=2,5)
   52 CONTINUE
      IF(ISWTCH(2).EQ.1) GO TO 50
      WRITE(6,122) (J,(INAME(K,J),K=1,5),J=6,11)
   50 CONTINUE
      J=12
      IF(ISWTCH(3).EQ.0) WRITE(6,122) J,(INAME(K,J),K=1,5)
      IF(ISWTCH(1).EQ.1) GO TO 54
      J=13
      WRITE(6,122) J,(INAME(K,J),K=1,5)
   54 CONTINUE
      J=14
      WRITE(6,122) J,(INAME(K,J),K=1,5)
  122 FORMAT(I8,10X,5A4)
      IF(ISWTCH(6).EQ.1) GO TO 125
C
C.......... CALL FOR WEATHER DATA
C
      CALL METDAT(DELTQ)
C
  125 CONTINUE
      IF(ISWTCH(2) .EQ. 1) GO TO 6020
      H=FLOAT(INCYC-1)*DELT
      IDD=H/23.9999
      IDD=IDD+1
      H=FLOAT(NQCYC)*DELT
      IDD2=H/23.9999
      DO 8000 KK=IDD,IDD2
 8000 READ(5,8010) TL(KK),SRI(KK),HDL(KK)
 8010 FORMAT(3F10.4)
 8020 CONTINUE
C
C
C..... CALL SUBROUTINE COEFF TO READ AND PRINT SYSTEM COEFFICIENTS
C
      CALL COEFF
C
C . . . . . . . . . . . . . . . . . . .  STEP  5
C..... READ MAXIMUM ALLOWABLE CONCENTRATIONS
C
  110 FORMAT(8F10.0)
      READ(5,110) (CLIMIT(K),K=1,NUMCON)
      CLIMIT(11)=CLIMIT(11)/AQCHA1(NJ)
      CLIMIT(12)=CLIMIT(12)/AQCHA2(NJ)
C
C . . . . . . . . . . . . . . . . . . .  STEP  6
C..... PRINT NETWORK AND HYDRAULIC PARAMETERS
C
      WRITE(6,193)
  193 FORMAT(1H1////42X,40H *****     SUMMARY OF HYDRAULIC INPUTS     **
     ****//86H ** JUNCTION HEAD AND HYD. RADIUS AND X-SECTIONAL AREA OF
     *CHANNELS ********************///
     *      80H*****************************    CHANNEL DATA    ********
     *********************      /
     *      80H CHAN.  LENGTH   WIDTH    AREA   MANNING  NET FLOW  HYD.
     *RADIUS  JUNC. AT ENDS     /)
      WRITE(6,194)             (N,CLEN(N),B(N),AREA(N),CN(N),QNET(N),
     * R(N),(NJUNC(N,K),K=1,2),N=1,NC)
  194 FORMAT(I5,2F8.0,F9.0,F8.3,F12.2,F10.1,I9,I6)
      WRITE(6,195)
  195 FORMAT(66H*********************  JUNCTION DATA    ***************
     ************ /48H    JUNC. INFLOW       AREA(FT2)  HEAD   CHANNELS/)
      WRITE(6,196) (J,QIN(J),ASUR(J),Y(J),(NCHAN(J,K),K=1,8),J=1,NJ)
  196 FORMAT(4X,I4,F9.1,3X,F11.0,F7.2,I5,7I4)
      WRITE(6,9101)
      WRITE(6,9103)   (Q(N), N=1,NC)
 9101 FORMAT(30H  FLOW DISTRIBUTION BY CHANNEL)
 9103 FORMAT(10F8.2)
C
      IF(N40.GT.0) GO TO 124
C
C . . . . . . . . . . . . . . . . . . .  STEP  7
C..... READ INITIAL JUNCTION QUALITY
C
      DO 126 L=1,NJ
      READ(5,200) J1,J2,(CTEMP(K),K=1,NUMCON)
  200 FORMAT(2I5,7F10.0/8F10.0)
      IF(J2.EQ.0) GO TO 130
      DO 129 J=J1,J2
      DO 128 K=1,NUMCON
  128 C(J,K)=CTEMP(K)
```

```
        CT(J)=C(J,1)
  129 CONTINUE
  126 CONTINUE
C
C . . . . . . . . . . . . . . . . .  STEP  8
C.....READ INITIAL TEMP IF TEMP IS NOT SIMULATED AND THIS IS A RESTART
C
  124 IF(ISWTCH(6) .EQ. 0) GO TO 8004
C
C
 8003 FORMAT(5(2I4,F8.0))
 8001 READ(5,8003) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 8002 I=1,5
      J1=JUN1(I)
      IF(J1 .EQ. 0) GO TO 8004
      J2=JUN2(I)
      DO 8002 J=J1,J2
      CT(J)=COEF(I)
 8002 CONTINUE
      GO TO 8001
 8004 CONTINUE
C
C......READ INFLOW QUALITY
C
  130 CONTINUE
      NN=18
      DO 164 J=1,NJ
      QOUT(J)=0.0
      QIN(J)=0.0
      DO 164 K=1,NUMCON
  164 CSPEC(J,K)=0.0
      DO 132 J=1,NJ
      READ(5,203) (NAME(K),K=1,20)
  203 FORMAT(20A4)
      READ(5,202) JJ,QQ,(CTEMP(K),K=1,NUMCON)
  202 FORMAT(I8,9F8.0/16X,8F8.0)
      IF(JJ.EQ.0) GO TO 166
      NN=NN+1
C
C . . . . . . . . . . . . . . . . .  STEP  9
C..... PRINT INFLOW QUALITY BY DISCHARGER
C
      IF(NN.LE.18) GO TO 160
      WRITE(6,243)
      NN=0
  160 CONTINUE
      WRITE(6,162)(NAME(K),K=1,20)
  162 FORMAT(1H0,20A4)
      WRITE(6,244) JJ,QQ,(CTEMP(K),K=1,NUMCON)
      IF(QQ.LE.0.0) GO TO 135
      DO 134 K=1,NUMCON
  134 CSPEC(JJ,K)=CTEMP(K)*QQ+CSPEC(JJ,K)
      QIN(JJ)=QIN(JJ)+QQ
      GO TO 132
  135 CONTINUE
      QOUT(JJ)=QOUT(JJ)-QQ
  132 CONTINUE
  166 CONTINUE
C
C . . . . . . . . . . . . . . . . . . .  STEP 10
C..... DETERMINE JUNCTION INFLOW QUALITY
C
      DO 170 J=1,NJ
      IF(QIN(J).LE.0.0) GO TO 170
      DO 172 K=1,NUMCON
  172 CSPEC(J,K)=CSPEC(J,K)/QIN(J)
      CHA1IN(J)=ALGIN1(J)
      CHA2IN(J)=ALGIN2(J)
      ALGIN1(J)=ALGIN1(J)/RACIN
      ALGIN2(J)=ALGIN2(J)/RACIN
C
  170 CONTINUE
      IF(N40 .EQ. 0) GO TO 136
C . . . . . . . . . . . . . . . . . . .  STEP 11
C..... READ RESTART TAPE
C
      READ(N40) (ALPHA(I),I=1,80)
      READ(N40) ((C(J,K),K=1,NUMCON),J=1,NJ)
      DO 154 J=JS,NJ
      ALG1(J)=ALG1(J)*AGCHA1(J)
      ALG2(J)=ALG2(J)*AGCHA2(J)
  154 CONTINUE
  243 FORMAT(45H      INFLOW QUALITY (MG/L EXCEPT AS NOTED)           /
     $' JUN FLOW(CFS) TEMP(C)      OXY   BOD-1   BOD-2   BOD-3   ORG-N
     $  NH3      NO2      NO3      PO4 CHL-A-1 CHL-A-2 COL/MPN   TOT-N'/)
  136 CONTINUE
  244 FORMAT(1X,I3,F10.2,12F8.3,E8.2,F8.3)
C
C . . . . . . . . . . . . . . . . . . .  STEP 13
C..... READ WASTE WATER RETURN FACTORS
C
C . . . . . . . . . . . . . . . . . . .  STEP 14
C..... READ AND APPLY FACTORS TO ADJUST INITIAL CONCENTRATIONS
C
      DO 222 I=1,NUMCON
      READ(5,112) NGROUP (I)
  112 FORMAT(I5)
      IF(NGROUP(I).LT.0) GO TO 239
      IF(NGROUP (I))222,222,218
  216 FORMAT(52H0NO MULTIPLICATION FACTOR APPLIED TO CONSTITUENT NO.I2/)
  218 NG = NGROUP (I)
      READ(5,220)            (FACTR(I,K),NJSTRT (I,K),NJSTOP(I,K),K=1,NG)
  220 FORMAT(F5.0,2I5,F5.0,2I5,F5.0,2I5,F5.0,2I5,F5.0,2I5)
  222 CONTINUE
      WRITE(6,224)
  224 FORMAT(70H1*****MULTIPLICATION FACTORS APPLIED TO OBTAIN STARTING
     *CONCENTRATIONS//
     *         51H CONSTITUENT    GROUP    FACTOR    JUNCTION NUMBERS)
      DO 230 I=1,NUMCON
      IF(NGROUP (I))230,230,226
  226 NG = NGROUP (I)
      WRITE(6,228)I,(K,FACTR(I,K),NJSTRT (I,K),NJSTOP(I,K),K=1,NG)
  228 FORMAT(1H //I8,I11,F11.2,I12,2H -,I4/
     *   (I19,F11.2,I12,2H -,I4))
  230 CONTINUE
      DO 232 I=1,NUMCON
      IF(NGROUP (I))231,231,232
  231 WRITE(6,216)I
  232 CONTINUE
      DO 238 M=1,NUMCON
      IF(NGROUP (M))238,238,233
  233 NG = NGROUP (M)
      DO 236 K=1,NG
      NJ1 = NJSTRT (M,K)
      NJ2=NJSTOP(M,K)
      DO 234 J=NJ1,NJ2
      C(J,M)=C(J,M)*FACTR(M,K)
  234 CONTINUE
  236 CONTINUE
  238 CONTINUE
  239 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP 15
C..... PRINT INITIAL QUALITY CONDITIONS
C
      NN=50
      DO 250 J=JS,NJ
      TEMP(J)=CT(J)
      IF(NCHAN(J,1).EQ.0) GO TO 250
      NN=NN+1
      IF(NN.LE.50) GO TO 252
      NN=1
      WRITE(6,241)
  241 FORMAT(47H1      INITIAL CONDITIONS (MG/L EXCEPT AS NOTED)      /
     $' JUN  TEMP(C)       OXY     OBOD1     OBOD2     OBOD3    ORG-N       N
     $H3       NO2       NO3       PO4   CHLA-1   CHLA-2  COL/MPN    TOT-N'
     $/)
  252 CONTINUE
      WRITE(6,242) J,(C(J,K),K=1,NUMCON)
      CHLA1(J)=ALG1(J)
      CHLA2(J)=ALG2(J)
      ALG1(J)=ALG1(J)/AGCHA1(J)
      ALG2(J)=ALG2(J)/AGCHA2(J)
  242 FORMAT(1X,I3,12F9.3,E9.2,F9.3)
  250 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP 16
C...... READ AND PRINT BOUNDARY CONCENTRATIONS
C
      READ(5,80)(KBOP(M),M=1,NUMCON)
      DO 187 M=1,NUMCON
  185 READ(5,184) CIN(M,1)
      IF(CIN(M,1) .LT. 0.) CIN(M,1)=-9.9E+19
  184 FORMAT(8F10.0)
  187 CONTINUE
      CIN(11,1)=CIN(11,1)/RACEX
      CIN(12,1)=CIN(12,1)/RACEX
  191 CONTINUE
C
      RETURN
      END
```

Subroutine COEFF

This subroutine reads in all spatially variant and spatially invariant system coefficients. After reading all coefficients, a report is generated listing each coefficient for each junction. A second report is generated detailing the nonvariant coefficients.

Before control leaves COEFF, an array of temperature adjustments for each coefficient is generated. These arrays are used in DYNQUA to set the coefficients that are temperature affected during each time step. Figure 10 is the flow chart for COEFF. If the user desires, COEFF will also calculate the reaeration coefficient internally.

All coefficients are input for 20°C, and assumes base e. COEFF adjusts the coefficients according to the time step used in the simulation.

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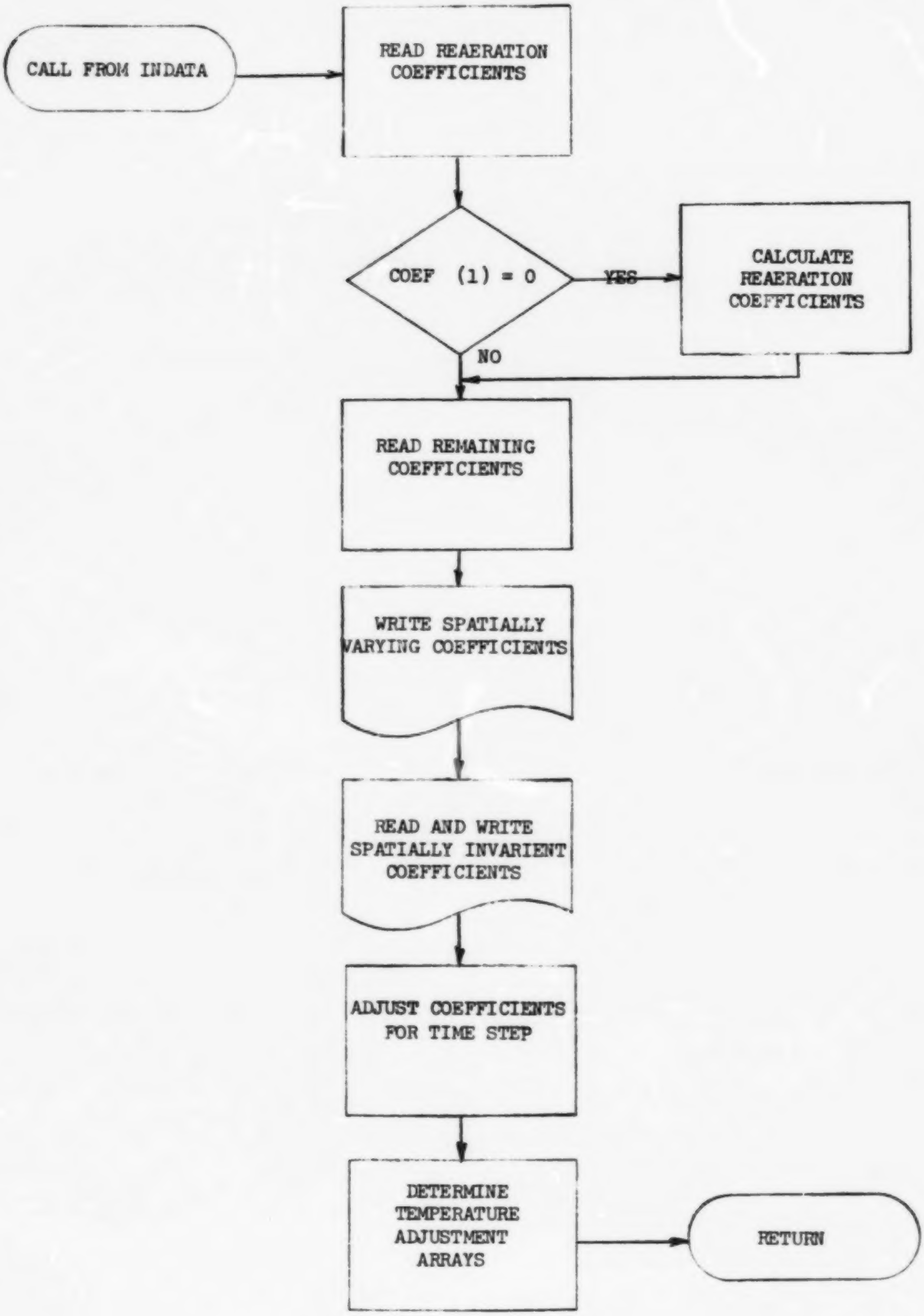
All coefficients are input for 20°C, and assumes base e. COEFF adjusts the coefficients according to the time step used in the simulation.

FIGURE D-9
FLOW CHART FOR COEFF


CALL FROM INDATA
READ REAERATION COEFFICIENTS
COEF (1) = 0
YES
CALCULATE REAERATION COEFFICIENTS
NO
READ REMAINING COEFFICIENTS
WRITE SPATIALLY VARYING COEFFICIENTS
READ AND WRITE SPATIALLY INVARIENT COEFFICIENTS
ADJUST COEFFICIENTS FOR TIME STEP
DETERMINE TEMPERATURE ADJUSTMENT ARRAYS
RETURN

```
      SUBROUTINE COEFF
C
C..... THIS SUBROUTINE READS VALUES FOR NUMEROUS COEFFICIENTS AND CONVERTS
C       THEM AS NECESSARY TO EQUIVALENT VALUES FOR THE COMPUTATIONAL TIME STEP
C
      COMMON/GEOM/YNEW(200),VOLWIN(200),VOL(200),ASUR(200),QIN(200),
     1            NCHAN(200,8),DIFFK(400),V(400),Q(400),AREA(400),
     2            B(400),CLEN(400),R(400),CN(400),NJUNC(400,2)
     3           ,QNET(200),Y(200),QOUT(200),VOLQOU(200)
     4,           YBAR(200),JGW,JS,NC,NJ
      COMMON/MISC/ALPHA(80),COIFFK,CIN(14,1),CLIMIT(14),CONST(20,14)
     A,      CTEMP(14),DELT,DTD,EBBCON(48,14),EXR,FACTR(14,10),IEXC
     B,      INCYC,INTBIG,IPRT,ITAPE(5),IWRINT,IWRITE,JDIV1(20),JDIV2(20)
     C,      JPRT(300),JRET1(20),JRET2(20),KBOP(14),KDCOP,KZOP,MM,NEXTPR
     D,      NEXTWR,NGROUP(14),NJSTOP(14,10),NJSTRT(14,10),NODYN,NOPRT
     E,      NQCYC,NQPRT,NRSTRT,NSPEC,NSTOP,NTAG,NUMCON,NUNITS,N10,N20
     F,      N30,N40,RETFAC(20,14),NEX,ISWTCH(10),NAME(20),INAME(5,14)
     G,      DELTQ,KDONE,MARK1,MARK2
C
C
      COMMON/INFL/TEMPIN(200),OXYIN(200),BODIN(200,3),CORGIN(200),
     $            CNH3IN(200),CNO2IN(200),CNO3IN(200),PO4IN(200),
     $            ALGIN1(200),ALGIN2(200),COLIN(200),TNIN(200),
     $            CHA1IN(200),CHA2IN(200)
C
C
      COMMON/CONC/TEMP(200),OXY(200),BOD(200,3),CORG(200),CNH3(200),
     $            CNO2(200),CNO3(200),PO4(200),ALG1(200),ALG2(200),
     $            COL(200),TN(200),CHLA1(200),CHLA2(200)
C
C
      COMMON/MASS/TEMPM(200),OXYM(200),BODM(200,3),CORGM(200),CNH3M(200)
     $           ,CNO2M(200),CNO3M(200),PO4M(200),ALG1M(200),
     $            ALG2M(200),COLM(200),TNM(200),CHLA1M(200),
     $            CHLA2M(200)
C
C
      COMMON/RATE/REOX(200),COLDK(200),BODDK(200,3),CNH3DK(200),
     $            CORGDK(200),EXPBO2(200),AGSNK1(200),AGSNK2(200),
     $            CNO2DK(200),POSINK(200),OXYBEN(200),CNHBEN(200),
     $            SECH1(200),PMAX1(200),PMAX2(200),AGCHA1(200),
     $            AGCHA2(200),PO4BEN(200),PRES1(200),PRES2(200),
     $            DFBIO1(200),DFBOD(200,3),DFCOL(200),DFNH3(200),
     $            DFNO2(200),DFOGN(200),DFBIO2(200),EXPBEN(200),
     $            EXPBO1(200),EXPBOD(200,3),EXPCOL(200),EXPNH3(200),
     $            EXPNO2(200),EXPORG(200),CHBEN(200),CSAT(200),
     $            OXBEN(200),OXDELT(200),POBEN(200),CFBOD,ALG1P,
     $            ALG1N,PSP1,PSN1,PSL1,ALG2P,ALG2N,PSP2,PSN2,PSL2,
     $            OXNH3,OXNO2,OXRES1,OXRES2,OXFAC1,OXFAC2,DKBOD,
     $            DKCOL,RACIN,RACEX
C
C
      COMMON/SUN/ TL(365),SRI(365),HDL(365)
C
C
      COMMON/ATMS/QC(200),QA(200),QE(200),EQTEM(200),XQNS(200),QTOT(200)
     A.     QNS(25,10),QNA(25,10),QRNETA(25,10),UWINDA(25,10),TAA(25,10)
     B.     TAWA(25,10),APA(25,10),CLOUD(25,10),IEQTEM,JWZONE(10,2)
     C.     QRNET(200),AX(4),BX(4),ALPH(8),BETA(8),PI,W80,DTOR
C
C
      COMMON/ICHECK/JIGNOR(200)
C
      DIMENSION C(200,14),CMASS(200,14),CSPEC(200,14)
      EQUIVALENCE (C(1,1),TEMP(1)),(CMASS(1,1),TEMPM(1))
     $            ,(CSPEC(1,1),TEMPIN(1))
C
C
C
C
C
      DIMENSION JUN1(5),JUN2(5),COEF(5)
      DIMENSION AWID(10,3)
C
C . . . . . . . . . . . . . . . . . .  STEP  1
C..... REAERATION (ASSIGNED OR CALCULATED)
C
  200 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
  100 FORMAT(5(2I4,F8.0))
      IF(COEF(1).LT.0.0) GO TO 206
      DO 202 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 204
      J2=JUN2(I)
      DO 202 J=J1,J2
      REOX(J)=COEF(I)
  202 CONTINUE
      GO TO 200
  206 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP  2
C..... CALCULATION OF REAERATION COEFFICIENTS, IF SO CHOSEN
C
      DO 18 J=1,NJ
      DEP=SQRT(Y(J))
      VAM=0.
      AC=0.
      DO 20 K=1,8
      N=NCHAN(J,K)
      IF(N.EQ.0) GO TO 22
      ABAR=CLEN(N)*B(N)
      VV=ABS(V(N))
      VAM=VAM+SQRT(VV)*ABAR/DEP
      AC=AC+ABAR
   20 CONTINUE
   22 CONTINUE
      REOX(J)=REOX(J)+VAM/AC
   18 CONTINUE
      DO 24 J=1,NJ
C     12.95=86400*SQRT(2.25E-8) - - SECONDS * MOLECULAR DIFFUSION COEFF
   24 REOX(J)=REOX(J)*12.95/(Y(J)*FLOAT(MM))
  204 CONTINUE
C
```

```
C . . . . . . . . . . . . . . . . . .  STEP  3
C.. COLIFORM BACTERIA DECAY
C
  210 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 212 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 214
      J2=JUN2(I)
      DO 212 J=J1,J2
      COLDK(J)=COEF(I)
  212 CONTINUE
      GO TO 210
  214 CONTINUE
C
C.. BOD DECAY
C
  220 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 222 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 224
      J2=JUN2(I)
      DO 222 J=J1,J2
      BODDK(J,1)=COEF(I)
  222 CONTINUE
      GO TO 220
  224 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 225 I=1,5
      J1=JUN1(I)
      IF(J1 .EQ. 0) GO TO 226
      J2=JUN2(I)
      DO 225 J=J1,J2
      BODDK(J,2)=COEF(I)
  225 CONTINUE
      GO TO 224
  226 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 227 I=1,5
      J1=JUN1(I)
      IF(J1 .EQ. 0)GO TO 228
      J2=JUN2(I)
      DO 227 J=J1,J2
      BODDK(J,3)=COEF(I)
  227 CONTINUE
      GO TO 226
  228 CONTINUE
C
C.. AMMONIA DECAY
C
  230 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 232 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 234
      J2=JUN2(I)
      DO 232 J=J1,J2
      CNH3DK(J)=COEF(I)
  232 CONTINUE
      GO TO 230
  234 CONTINUE
```

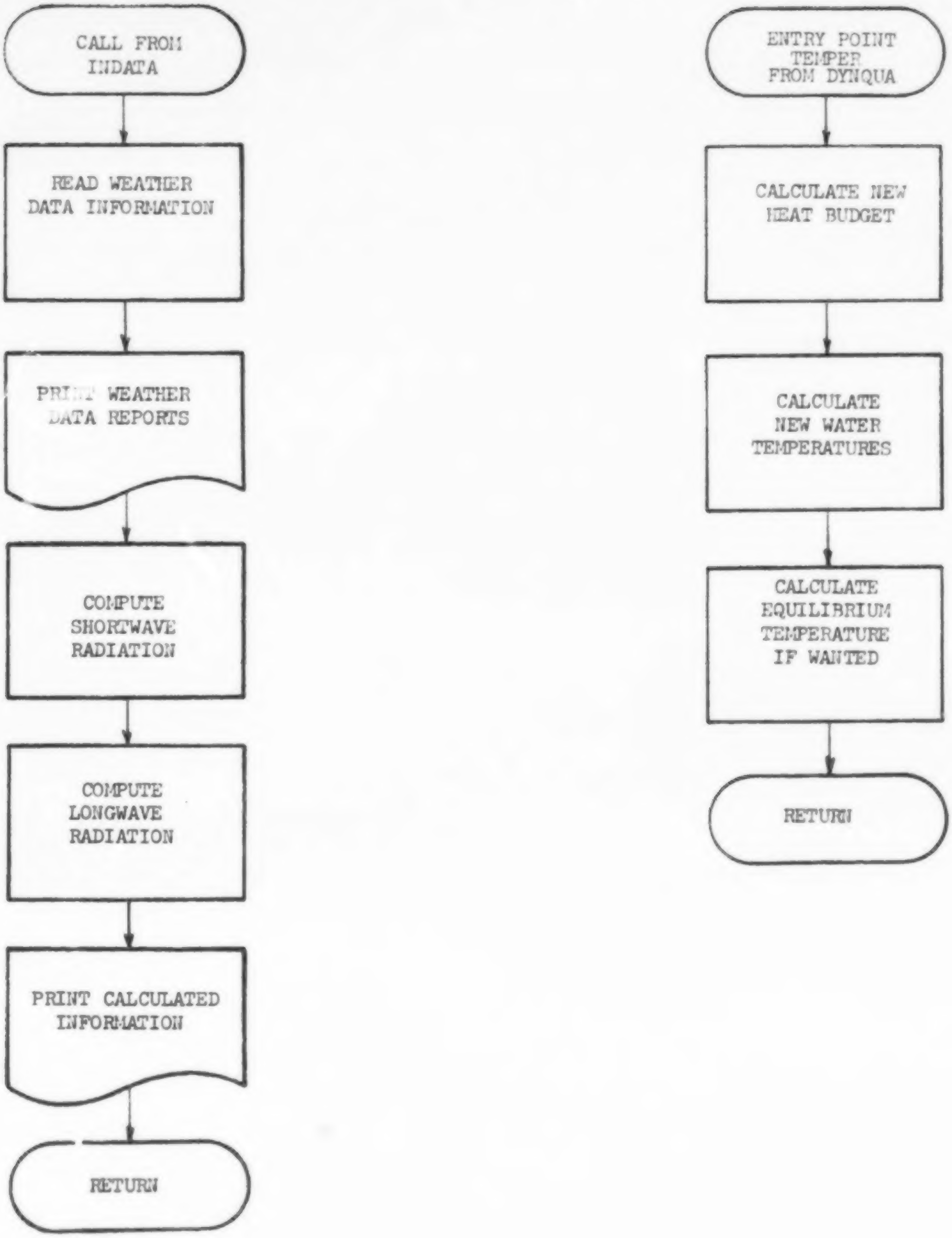
```
C
C.. NITRITE DECAY
C
  240 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 242 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 244
      J2=JUN2(I)
      DO 242 J=J1,J2
      CNO2DK(J)=COEF(I)
  242 CONTINUE
      GO TO 240
  244 CONTINUE
C
C...ORGANIC NITROGEN DECAY
C
  250 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 252 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 254
      J2=JUN2(I)
      DO 252 J=J1,J2
      CORGDK(J)=COEF(I)
  252 CONTINUE
      GO TO 250
  254 CONTINUE
C
C.....ALGAE SINK RATES FT/DAY
C
  270 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 272 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 274
      J2=JUN2(I)
      DO 272 J=J1,J2
      AGSNK1(J)=COEF(I)
  272 CONTINUE
      GO TO 270
  274 CONTINUE
  280 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 282 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 284
      J2=JUN2(I)
      DO 282 J=J1,J2
      AGSNK2(J)=COEF(I)
  282 CONTINUE
      GO TO 280
  284 CONTINUE
C
C.....ALGAE RESPIRATION RATES 1/DAY
C
  300 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 302 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 304
      J2=JUN2(I)
      DO 382 J=J1,J2
      PRES1(J)=COEF(I)
  382 CONTINUE
      GO TO 380
  384 CONTINUE
  390 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 392 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 394
      J2=JUN2(I)
      DO 392 J=J1,J2
      PRES2(J)=COEF(I)
  392 CONTINUE
      GO TO 390
  394 CONTINUE
C
C..... PHOSPHATE REMOVAL (NET SINK) RATE -- INCLUDING UPTAKE-EXCHANGE
C       OR PRECIPITATION,AND SETTLING
C
  290 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 292 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 294
      J2=JUN2(I)
      DO 292 J=J1,J2
      POSINK(J)=COEF(I)
  292 CONTINUE
      GO TO 290
  294 CONTINUE
C
C..... PHOSPHATE BENTHIC SOURCE RATE -- RELEASE FROM DECAYING ORGANIC SED
C
  300 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 302 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 304
      J2=JUN2(I)
      DO 302 J=J1,J2
      PO4BEN(J)=COEF(I)
  302 CONTINUE
      GO TO 300
  304 CONTINUE
C
C.. BENTHIC UPTAKE RATE OF OXYGEN
C
  310 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 312 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 314
      J2=JUN2(I)
      DO 312 J=J1,J2
      OXYBEN(J)=COEF(I)
  312 CONTINUE
      GO TO 310
  314 CONTINUE
C
C..... AMMONIA SOURCE RATE -- RELEASE FROM DECAYING ORGANIC SEDIMENT
```

```
C
  320 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 322 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 324
      J2=JUN2(I)
      DO 322 J=J1,J2
      CNMBEN(J)=COEF(I)
  322 CONTINUE
      GO TO 320
  324 CONTINUE
C
C..... SECCHI DISC
C
  330 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 332 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 334
      J2=JUN2(I)
      DO 332 J=J1,J2
      SECHI(J)=COEF(I)
  332 CONTINUE
      GO TO 330
  334 CONTINUE
C
C......ALGAE MAXIMUM GROWTH RATES 1/DAY
C
  340 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 342 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 344
      J2=JUN2(I)
      DO 342 J=J1,J2
      PMAX1(J)=COEF(I)
  342 CONTINUE
      GO TO 340
  344 CONTINUE
  350 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 352 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 354
      J2=JUN2(I)
      DO 352 J=J1,J2
      PMAX2(J)=COEF(I)
  352 CONTINUE
      GO TO 350
  354 CONTINUE
C
C......RATIOS OF CHL-A TO BIOMASS MG/MG
C
  360 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 362 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 364
      J2=JUN2(I)
      DO 362 J=J1,J2
      AGCHA1(J)=COEF(I)
  362 CONTINUE
      GO TO 360
  364 CONTINUE
  370 READ(5,100) (JUN1(I),JUN2(I),COEF(I),I=1,5)
      DO 372 I=1,5
      J1=JUN1(I)
      IF(J1.EQ.0) GO TO 374
      J2=JUN2(I)
      DO 372 J=J1,J2
      AGCHA2(J)=COEF(I)
  372 CONTINUE
      GO TO 370
  374 CONTINUE
C
C     EDDY DIFFUSION COEFICIENTS READ HERE BY JUNCTIONS
C
 1000 READ(5,100)  (JUN1(I),JUN2(I),COEF(I), I=1,5)
      DO 1002 I=1,5
      J1=JUN1(I)
      IF (J1.EQ.0) GO TO 1004
      J2=JUN2(I)
      DO 1002 J=J1,J2
      DIFFK(J)= COEF(I)
 1002 CONTINUE
      GO TO 1000
 1004 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP  4
C..... WRITE SPATIALLY VARYING COEFFICIENTS
C
      WRITE(6,140)
      DO 180 J=1,NJ
      IF(NCHAN(J,1).EQ.0)  GO TO 180
      WRITE(6,141) J,REOX(J),BODDK(J,1),BODDK(J,2),BODDK(J,3),CORGDK(J),
     3 CNH3DK(J),CNO2DK(J),
     1  PMAX1(J),PMAX2(J),PRES1(J),PRES2(J),AGCHA1(J),AGCHA2(J),
     2  OXYBEN(J),PO4BEN(J),CNHBEN(J),AGSNK1(J),DIFFK(J)
  180 CONTINUE
  140 FORMAT(1H1,45X,30HSPATIALLY VARYING COEFFICIENTS/,
     1' JUN OXYGEN  CBOD1  CBOD2  CBOD3  ORG-N    NH3    NO2  ALG-1  ALG
     2-2  ALG-1  ALG-2  RATIO  RATIO OXYBEN   PHOS  NH3-N  ALG-1   EDDY'
     3/,6X,'REAER  DECAY  DECAY  DECAY  DECAY  DECAY  DECAY GROWTH GROWT
     4H   RESP   RESP CHLA-1 CHLA-2  SINK SOURCE SOURCE   SINK   DIFF',
     5/,6X,'1/DAY  1/DAY  1/DAY  1/DAY  1/DAY  1/DAY  1/DAY  1/DAY  1/DA
     6Y  1/DAY  1/DAY                       ---   MG/ FT2/DAY--- FT/DAY FT2/S',
     7/)
  141 FORMAT(I4,18F7.2)
C
C . . . . . . . . . . . . . . . . . .  STEP  5
C..... SPATIALLY INVARIANT COEFFICIENTS
C
C..... ALGAE RELATED COEFFICIENTS
C
  110 FORMAT(8F10.0)
      READ(5,110)ALG1P,ALG1N,PSP1,PSN1,PSL1
      READ(5,110)ALG2P,ALG2N,PSP2,PSN2,PSL2
      READ(5,110) OXNO2,OXNH3,OXRES1,OXRES2,OXFAC1,OXFAC2
      READ(5,110) RACIN,RACEA
C
C***** TEMPERATURE COEFFICIENTS
C
      DO 9138 I=1,10
 9138 READ(5,9137)   (AQ10(I,J), J=1,3)
 9137 FORMAT(3F10.0)
C
C***** STOICHIOMETRIC EQUIVALENCES
C
C
C . . . . . . . . . . . . . . . . . .  STEP  6
C***** PRINT SPATIALLY INVARIANT COEFFICIENTS
C
      WRITE(6,136)
  135 FORMAT(1H1,///,45H SPATIALLY INVARIANT SYSTEM COEFFICIENT      //)
      WRITE(6,144)   ((AQ10(I,J),J=1,3),I=1,10)
  144 FORMAT(//,40H Q10 TEMPERATURE COEFFICIENTS                      ,/
     $              40H      COLIFORM DIE OFF                       ,3(F10.3)/
     $              40H      BOD-1 DECAY                            ,3(F10.3)/
     $              40H      BOD-2 DECAY                            ,3(F10.3)/
     $              40H      BOD-3 DECAY                            ,3(F10.3)/
     $              40H      AMMONIA DECAY                          ,3(F10.3)/
     $              40H      NITRITE DECAY                          ,3(F10.3)/
     $              40H      ORGANIC SEDIMENT DECAY                 ,3(F10.3)/
     $              40H      ORGANIC N DECAY                        ,3(F10.3)/
     $              40H      ALG-1 GROWTH AND RESPIRATION           ,3(F10.3)/
     $              40H      ALG-2 GROWTH AND RESPIRATION           ,3(F10.3))
      WRITE(6,146) OXNO2,OXNH3,OXRES1,OXRES2,OXFAC1,OXFAC2
  146 FORMAT(//,48H STOICHIOMETRIC EQUIVALENCE BETWEEN OXYGEN AND   ,/
     $              40H      NITRITE DECAY                          ,F10.3/
     $              40H      AMMONIA DECAY                          ,F10.3/
     $              40H      ALG-1 RESPIRATION=OXRES1*CHL-A         ,F10.3/
     $              40H      ALG-2 RESPIRATION=OXRES2*CHL-A         ,F10.3/
     $              40H      ALG-1 GROWTH =OXFAC1*CHL-A             ,F10.3/
     $              40H      ALG-2 GROWTH =OXFAC2*CHL-A             ,F10.3)
      WRITE(6,148) PSP1,PSP2,PSN1,PSN2,PSL1,PSL2
  148 FORMAT(//40H HALF-SATURATION CONSTANTS FOR ALGAE                  ,/
     $   '     ALG-1 P',10X,F10.3,10X,'     ALG-2 P',10X,F10.3/,
     $   '     ALG-1 N',10X,F10.3,10X,'     ALG-2 N',10X,F10.3,/,
     $   '     ALG-1 L',10X,F10.3,10X,'     ALG-2 L',10X,F10.3,///)
      WRITE(6,150) ALG1P,ALG2P,ALG1N,ALG2N
  150 FORMAT(//,40H CHEMICAL COMPOSITION OF ALGAE                ,/
     $'        ALG-1 P',10X,F10.3,'    ALG-2 P',10X,F10.3,/,
     $'        ALG-1 N',10X,F10.3,'    ALG-2 N',10X,F10.3,/)
      WRITE(6,155) RACIN,RACEA
  155 FORMAT(//,40H RATIO OF CHLOROPHYLL A TO ALGAE               ,/
     $              40H      FOR ALL INFLOWS                            ,F10.2,/
     $              40H      FOR EXCHANGE                               ,F10.2,/)
C
C . . . . . . . . . . . . . . . . . .  STEP  7
C***** ADJUST COEFFICIENTS FOR TIME STEP
C
      DKBOD=BODDK(JGW,1)
      DKCOL=COLDK(JGW)
      DO 400 J=1,NJ
      SECHI(J)=1.90/SECHI(J)
      REOX(J)=1.0-EXP(-REOX(J)*DTD)
      COLDK(J)=EXP(-COLDK(J)*DTD)-1.0
      BODDK(J,1)=EXP(-BODDK(J,1)*DTD)-1.0
      BODDK(J,2)=EXP(-BODDK(J,2)*DTD)-1.0
      BODDK(J,3)=EXP(-BODDK(J,3)*DTD)-1.0
      CNH3DK(J)=EXP(-CNH3DK(J)*DTD)-1.0
      CNO2DK(J)=EXP(-CNO2DK(J)*DTD)-1.0
      CORGDK(J)=EXP(-CORGDK(J)*DTD)-1.0
      PMAX1(J)=EXP(PMAX1(J)*DTD)-1.0
      PMAX2(J)=EXP(PMAX2(J)*DTD)-1.0
      PRES1(J)=EXP(PRES1(J)*DTD)-1.0
      PRES2(J)=EXP(PRES2(J)*DTD)-1.0
      AGSNK1(J)=AGSNK1(J)*DTD
      AGSNK2(J)=AGSNK2(J)*DTD
      POSINK(J)=POSINK(J)*DTD
      OXYBEN(J)=OXYBEN(J)*DTD*.035314667
      CNHBEN(J)=CNHBEN(J)*DTD*.035314667
      PO4BEN(J)=PO4BEN(J)*DTD*.035314667
  400 CONTINUE
C
C . . . . . . . . . . . . . . . . . .  STEP  8
C..... SET TEMPERATURE DEPENDENT ARRAYS
C
      DO 62 I=1,50
      TA=FLOAT(I)-20.
      TB=FLOAT(I)
      Q10COL=AQ10(1,1)    +   AQ10(1,2)*TB   +   AQ10(1,3)*TB*TB
      Q10BOD=AQ10(2,1)    +   AQ10(2,2)*TB   +   AQ10(2,3)*TB*TB
      QBOD22=AQ10(3,1)    +   AQ10(3,2)*TB   +   AQ10(3,3)*TB*TB
      QBOD33=AQ10(4,1)    +   AQ10(4,2)*TB   +   AQ10(4,3)*TB*TB
      Q10NH3=AQ10(5,1)    +   AQ10(5,2)*TB   +   AQ10(5,3)*TB*TB
      Q10NO2=AQ10(6,1)    +   AQ10(5,2)*TB   +   AQ10(6,3)*TB*TB
      Q10BEN=AQ10(7,1)    +   AQ10(7,2)*TB   +   AQ10(7,3)*TB*TB
      Q10ORG=AQ10(8,1)    +   AQ10(8,2)*TB   +   AQ10(8,3)*TB*TB
      Q10BO1=AQ10(9,1)    +   AQ10(9,2)*TB   +   AQ10(9,3)*TB*TB
      Q10BO2=AQ10(10,1)    +   AQ10(10,2)*TB   +   AQ10(10,3)*TB*TB
      EXPBEN(I)=Q10BEN**TA
      EXPBO1(I)=Q10BO1**TA
      EXPBO2(I)=Q10BO2**TA
      EXPCOL(I)=Q10COL**TA
      EXPBOD(I,1)=Q10BOD**TA
      EXPBOD(I,2)=QBOD22**TA
      EXPBOD(I,3)=QBOD33**TA
      EXPNO2(I)=Q10NO2**TA
      EXPNH3(I)=Q10NH3**TA
      EXPORG(I)=Q10ORG**TA
   62 CONTINUE
C
      RETURN
      END
```

Subroutine METDAT

This subroutine consists of two separate sections (METDAT and TEMPER). The first section is called from INDATA and is used to input all required meterological data needed by the simulation run. (If temperature is not simulated, METDAT and TEMPER are never called.) METDAT reads in the number of weather zones, and the number of observations in the data deck. It produces a report listing the information. Before returning to INDATA, METDAT calculates the initial best balance for the simulation run. TEMPER (an entry point of METDAT) is called during the main quality loop. Its purpose is to calculate the best budget as the simulation proceeds through time. Figure 11 provides the flow chart for METDAT.

FIGURE D-10
FLOW CHART FOR METDAT AND TEMPER

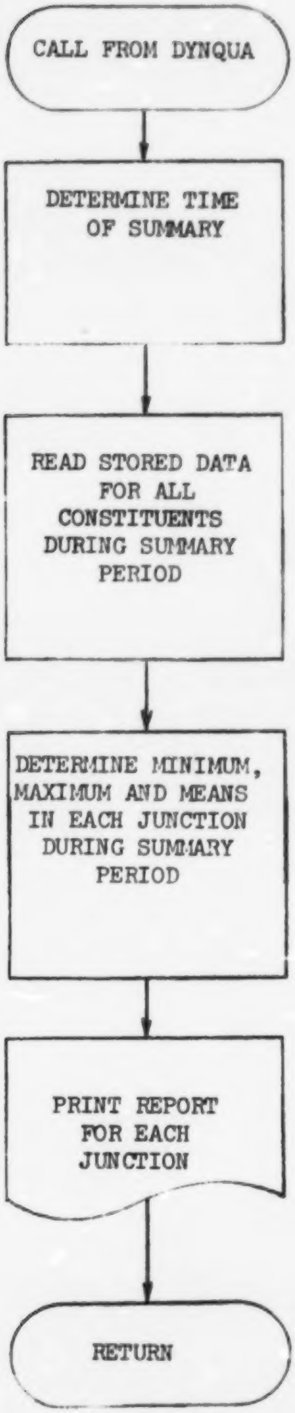

CALL FROM INDATA
READ WEATHER DATA INFORMATION
PRINT WEATHER DATA REPORTS
COMPUTE SHORTWAVE RADIATION
COMPUTE LONGWAVE RADIATION
PRINT CALCULATED INFORMATION
RETURN
ENTRY POINT TEMPER FROM DYNQUA
CALCULATE NEW HEAT BUDGET
CALCULATE NEW WATER TEMPERATURES
CALCULATE EQUILIBRIUM TEMPERATURE IF WANTED
RETURN

```
      SUBROUTINE METDAT(DELTQ)
      COMMON/ATMS/QC(200),QW(200),QE(200),EQTEM(200),XQNS(200),QTOT(200)
     A,     QNS(25,10),QNA(25,10),QRNETA(25,10),UWINDA(25,10),TAA(25,10)
     B,     TAWA(25,10),APA(25,10),CLOUD(25,10),IEQTEM,JWZONE(10,2)
     C,     QRNET(200),A(4),B(4),ALPH(5),BETA(8),PI,WBO,DTOR
      DIMENSION TEMP(200),TEMPM(200),VOL(200),ASUR(200)
C
C . . . . . . . . . . . . . . . . . .  STEP  1
C..... READ AND PRINT WEATHER DATA
C
      READ(5,100) NWZONE,NPTS,NQCSM,NRCALC,IEQTEM,IDAY
      DO 500 L=1,NWZONE
      READ(5,90) (JWZONE(L,I),I=1,2),XLAT,XLON,EPS,TURB,AA,BB
   90 FORMAT(2I5,7F10.0)
  100 FORMAT(16I5)
  102 FORMAT(8F10.0)
      DAY=IDAY
      WRITE(6,104) L,(JWZONE(L,I),I=1,2),XLAT,XLON,TURB,IDAY,AA,BB
  104 FORMAT(1H1,///40H1 WEATHER DATA SUMMARY FOR WEATHER ZONE    ,I2,
     A      11H, JUNCTION   ,I3,13H TO JUNCTION  ,I3/,
     C    20H0 LATITUDE             F10.1,/
     120H0 LONGITUDE           ,F10.1/20H0 ATMOS TURBIDITY     ,F10.1/
     220H0 DAY OF YEAR         ,  I10/
     320H0 EVAP A              ,E10.3,/20H0 EVAP B             E10.3)
      INT=3600*24/(NPTS-1)
      DO 200 I=1,NPTS
      READ(5,102) QRNETA(I,L),UWINDA(I,L),CLOUD(I,L),TAA(I,L),
     A              TAAA(I,L),APA(I,L)
      IF(UWINDA(I,L).LT.0.05) UWINDA(I,L)=0.05
  200 CONTINUE
C
      SMERD=15*IFIX(XLON/15.0)
      DELTS=EPS*(SMERD-XLON)/15.0
      DECL = 0.4092 * COS( 0.01721 * ( 172.0 - DAY ) )
      TA = TAN( XLAT * DTOR ) * TAN( DECL )
      HSR = 12.0 * ACOS( - TA ) / PI
      SUNUP = 12.0 - HSR + DELTS
      SUNSET = 12.0 + HSR + DELTS
      T1 = SIN( DECL ) * SIN( XLAT * DTOR )
      T2 = COS( DECL ) * COS( XLAT * DTOR )
C
C . . . . . . . . . . . . . . . . . .  STEP  2
C....                          COMPUTE LONGWAVE ATMOSPHER. RADIATION
C
      DO 132 NN=1,NPTS
      TA=1.23E-16*(1.0+0.17*CLOUD(NN,L)**2)
      QNA(NN,L)=TA*(TAWA(NN,L)+273.0)**6
  132 CONTINUE
C
C....                          SHORTWAVE SOLAR RADIATION
C
      DO 130 NN=1,NPTS
      QNS(NN,L)=0.0
      TIME=(2*NN-1)*INT/7200
  125 IF(TIME .LE. SUNUP .OR. TIME .GE. SUNSET) GO TO 131
      CLD=CLOUD(NN,L)
      HA = PI * ( TIME - 12.0 - DELTS ) / 12.0
      SINA = T1 + T2 * COS( HA )
      RAD = Q00 * SINA
      AI = 0.128 - 0.054 * ALOG10( 1.0 / ABS( SINA ) )
      TA = TURB * AI / SINA
      RAD = RAD / EXP( TA )
      RAD = RAD * (1.0 - .65 * CLD**2)
      NC= 2.0 * (CLD +1.0)
      IF(CLD .GT. 0.05 .AND. CLD .LT. 0.95) GO  TO 150
      NC=1
      IF(CLD .GT. 0.95) NC=4
  150 ALBEDO = A(NC) * ( 57.3 * ASIN( SINA ) ) ** B(NC)
      QNS(NN,L)=RAD*(1.0-ALBEDO)
  131 CONTINUE
      IF(NRCALC.NE.1) QRNETA(NN,L)=QNS(NN,L)+QNA(NN,L)
  130 CONTINUE
C
      IDQ=IFIX(DELTQ)
      FINT=FLOAT(INT)
C
C . . . . . . . . . . . . . . . . . .  STEP  3
C..... PRINT REMAINING WEATHER DATA
C
      WRITE(6,112)
  112 FORMAT(///
     1110H      INCOMING         WIND       CLOUD     DRY BULB      WET BULB
     2 ATMOSPHERIC  SHORT WAVE       LONG WAVE                            /
     3110H    RADIATION        SPEED      COVER  TEMPERATURE  TEMPERATURE
     4   PRESSURE   SOLAR(CALC)      SOLAR(CALC)                          /
     5110H  (KCAL/M2/SEC)   (M/SEC)   FRACTION     (C)            (C)
     6       (MB)   (KCAL/M2/SEC)   (KCAL/M2/SEC)                         )
      DO 136 I=1,NPTS
      WRITE(6,110) QRNETA(I,L),UWINDA(I,L),CLOUD(I,L),TAA(I,L),
     A               TAWA(I,L),APA(I,L),QNS(I,L),QNA(I,L)
  136 CONTINUE
  110 FORMAT(1H F10.4,F12.1,F10.1,F11.1,F13.1,F13.0,F14.4,F17.4)
  500 CONTINUE
      RETURN
C
      ENTRY TEMPER(TEMP,TEMPM,VOL,ASUR)
C
C . . . . . . . . . . . . . . . . . .  STEP  4
C..... DETERMINE NECESSARY INTERPOLATION DATA
C
      NQCSM=NQCSM+1
      ITIM=NQCSM*IDQ
      ITIT=ITIM-(ITIM/86400)*86400
      I=ITIT/INT
      FACT=FLOAT(ITIT-I*INT)/FINT
      I=I+1
      JJ=I+1
      IF(JJ.GT.NPTS) JJ=1
C
C . . . . . . . . . . . . . . . . . .  STEP  5
C..... INTERPOLATE BETWEEN WEATHER DATA POINTS
C
      DO 300 L=1,NWZONE
      J1=JWZONE(L,1)
      J2=JWZONE(L,2)
      QNET=(QRNETA(JJ,L)-QRNETA(I,L))*FACT+QRNETA(I,L)
      UWIND=(UWINDA(JJ,L)-UWINDA(I,L))*FACT+UWINDA(I,L)
      TAIR=(TAA(JJ,L)-TAA(I,L))*FACT+TAA(I,L)
      TWAT=(TAWA(JJ,L)-TAWA(I,L))*FACT+TAWA(I,L)
      AP=(APA(JJ,L)-APA(I,L))*FACT+APA(I,L)
C.......... RHOW = 0.935 * 1025. (SPECIFIC HEAT * DENSITY OF SEA WATER)
      RHOW=960.
      EA=2.1718E8*EXP(-4157.0/(TWAT+239.09))
     $   -AP*(TAIR-TWAT)*(6.6E-4+7.59E-7*TWAT)
      TII=RHOW*(AA+BB*UWIND)
C
C . . . . . . . . . . . . . . . . . .  STEP  6
C..... HEAT BUDGET TERMS AND NEW WATER TEMPETATURE
C
      DO 310 J=J1,J2
      QRNET(J)=QNET
      XQNS(J)=(QNS(JJ,L)-QNS(I,L))*FACT+QNS(I,L)
      TWC=TEMP(J)
      HV=597.0-0.57*TWC
      ES=2.1718E8*EXP(-4157.0/(TWC+239.09))
      ROXDR=1.0/((VOL(J)*304.8)/ASUR(J))
      TI=TII*HV
      QE(J)=TI*(ES-EA)
      IF(QE(J).LE.0.0) QE(J)=0.0
      QC(J)=0.61*TI*(TWC-TAIR)
      QW(J)=0.0736+0.00117*TWC
      QTOT(J)=QRNET(J)-QE(J)-QC(J)-QW(J)
      TEMPW(J)=TEMPW(J)+QTOT(J)*DELTQ*ROXDR*VOL(J)
      IF(IEQTEM.EQ.0) GO TO 420
C
C . . . . . . . . . . . . . . . . . .  STEP  7
C..... DETERMINT EQULIBRIUM TEMPERATURE IF REQUESTED
C
  422 CONTINUE
      IF(TWC.GE.40.0) TWC=39.99
      IF(TWC.LT.0.0) TWC=0.0
      NN=IFIX(TWC)/5+1
      T2=BETA(NN)+6.1E-4*AP
      T3=ALPH(NN)-EA-6.1E-4*AP*TAIR
      XCHCF=0.0117+TI*T2
      DNUM=QRNET(J)-0.0736-TI*T3
      EQTEM(J)=DNUM/XCHCF
      DTEM=TWC-EQTEM(J)
      TEM2=EQTEM(J)+DTEM*EXP(-ROXDR*XCHCF*DELTQ)
      II=IFIX(TEM2)/5+1
      IF(NN.EQ.II) GO TO 420
      TWC=TEM2
      GO TO 422
  420 CONTINUE
  310 CONTINUE
  300 CONTINUE
      RETURN
      END
      SUBROUTINE BLOCK
C
C..... THIS BLOCK DATA SUPPLIES SPECIFIC INVARIANT INFORMATION
C
      COMMON/MISC/ALPHA(80),CDIFFK,CIN(14,1),CLIMIT(14),CONST(20,14)
     A.     CTEMP(14),DELT,DT0,EBBCON(46,14),EXN,FACTR(14,10),IEXC
     B.     INCYC,INTBIG,IPRT,ITAPE(5),IWRINT,IWRITE,JDIV1(20),JDIV2(20)
     C.     JPRT(300),JRET1(20),JRET2(20),KBOP(14),KDCOP,KZOP,MM,NEXTPR
     D.     NEXTWR,NGROUP(14),NJSTOP(14,10),NJSTRT(14,10),NODYN,NOPRT
     E.     NQCYC,NQPRT,NRSTRT,NSPEC,NSTOP,NTAG,NUMCON,NUNITS,N10,N20
     F.     N30,N40,RETFAC(20,14),NEX,ISWTCH(10),NAME(20),INAME(5,14)
     G.     DELTQ,KOUNE,MARK1,MARK2
C
C
      COMMON/ATMS/QC(200),QW(200),QE(200),EQTEM(200),XQNS(200),QTOT(200)
     A.     QNS(25,10),QNA(25,10),QRNETA(25,10),UWINDA(25,10),TAA(25,10)
     B.     TAWA(25,10),APA(25,10),CLOUD(25,10),IEQTEM,JWZONE(10,2)
     C.     QRNET(200),A(4),B(4),ALPH(8),BETA(8),PI,WBO,DTOR
C
C..... CONSTITUENT TITLES
C
      DATA INAME/4HTEMP,4HERAT,4HURE ,4H    ,4H
     A.          4HDISS,4HOLVE,4HD OX,4HYGEN,4H
     B.          4HCARB,4HONAC,4HEOUS,4H BOD,4H-1
     8.          4HCARB,4HONAC,4HEOUS,4H BOD,4H-2
     9.          4HCARB,4HONAC,4HEOUS,4H BOD,4H-3
     C.          4HORGA,4HNIC ,4HNITR,4HOGEN,4H
     D.          4HAMMO,4HNIA ,4HNITR,4HOGEN,4H
     E.          4HNITR,4HITE ,4HNITR,4HOGEN,4H
     F.          4HNITR,4HATE ,4HNITR,4HOGEN,4H
     G.          4HPHOS,4HPHAT,4HE PH,4HOSPH,4HORUS
     2.          4HCHLO,4HROPH,4HYLL ,4HA--1,4H
     1.          4HCHLO,4HROPH,4HYLL ,4HA--2,4H
     H.          4HCOLI,4HFORM,4H BAC,4HTERI,4HA
     J.          4HTOTA,4HL NI,4HTROG,4HEN  ,4H
C
C..... INITIALIZATION OF METEROLOGIC CONSTANTS
C
      DATA XQNS/200*1.0/
      DATA ALPH/6.05,5.10,2.65,-2.04,-9.94,-22.29,-40.63,-66.90/
      DATA BETA 0.522,0.710,0.954,1.265,1.659,2.151,2.761,3.511/
      DATA A/1.18,2.20,0.95,0.35/
      DATA B/-0.77,-0.97,-0.75,-0.45/
      DATA PI/3.14159/, WBO/0.3333333/, DTOR/0.01745/
      RETURN
      END
```

Subroutine QUALEX

QUALEX produces a summary of all water quality information that is handled by the simulation over a specified time. Information concerning the concentrations of each constituent at each junction and time step can be stored on tape or file during every time step if desired. At user intervals, QUALEX then produces a specified summary of all stored data, determining the minimum value, the maximum value and the mean during the interval for each junction. A report is generated to display the calculated summaries. The flow chart for QUALEX is shown in Figure 13.

FIGURE D-11
FLOW CHART FOR QUALEX


CALL FROM DYNQUA
DETERMINE TIME OF SUMMARY
READ STORED DATA FOR ALL CONSTITUENTS DURING SUMMARY PERIOD
DETERMINE MINIMUM, MAXIMUM AND MEANS IN EACH JUNCTION DURING SUMMARY PERIOD
PRINT REPORT FOR EACH JUNCTION
RETURN

```
      SUBROUTINE QUALEX
      COMMON/GEOM/YNEW(200),VOLQIN(200),VOL(200),ASUR(200),QIN(200),
     1           NCHAN(200,8),DIFFK(400),V(400),Q(400),AREA(400),
     2           B(400),CLEN(400),R(400),CN(400),NJUNC(400,2)
     3          ,QNET(200),Y(200),QOUT(200),VOLQOU(200)
     4,          YBAR(200),JGW,JS,NC,NJ
      COMMON/MISC/ALPHA(80),CDIFFK,CIN(14,1),CLIMIT(14),CONST(20,14)
     A,    CTEMP(14),DELT,DTD,EBBCON(48,14),EXM,FACTR(14,10),IEXC
     B,    INCYC,INTBIG,IPRT,ITAPE(5),IWRINT,IWRITE,JDIV1(20),JDIV2(20)
     C,    JPRT(300),JRET1(20),JRET2(20),KBOP(14),KDCOP,KZOP,MM,NEXTPR
     D,    NEXTWR,NGROUP(14),NJSTOP(14,10),NJSTRT(14,10),NODYN,NOPRT
     E,    NQCYC,NQPRT,NRSTRT,NSPEC,NSTOP,NTAG,NUMCON,NUNITS,N10,N20
     F,    N30,N40,RETFAC(20,14),NEX,ISWTCH(10),NAME(20),INAME(5,14)
     G,    DELTQ,KDONE,MARK1,MARK2
C
C
      COMMON/INFL/TEMPIN(200),OXYIN(200),BODIN(200,3),CORGIN(200),
     $           CNH3IN(200),CNO2IN(200),CNO3IN(200),PO4IN(200),
     $           ALGIN1(200),ALGIN2(200),COLIN(200),TNIN(200),
     $           CHA1IN(200),CHA2IN(200)
C
C
      COMMON/CONC/TEMP(200),OXY(200),BOD(200,3),CORG(200),CNH3(200),
     $           CNO2(200),CNO3(200),PO4(200),ALG1(200),ALG2(200),
     $           COL(200),TN(200),CHLA1(200),CHLA2(200)
C
C
      COMMON/MASS/TEMPM(200),OXYM(200),BODM(200,3),CORGM(200),CNH3M(200)
     $           ,CNO2M(200),CNO3M(200),PO4M(200),ALG1M(200),
     $           ALG2M(200),COLM(200),TNM(200),CHLA1M(200),
     $           CHLA2M(200)
C
C
      COMMON/RATE/REOX(200),COLDK(200),BODDK(200,3),CNH3DK(200),
     $           CORGDK(200),EXPBO2(200),AGSNK1(200),AGSNK2(200),
     $           CNO2DK(200),POSINK(200),OXYBEN(200),CNHBEN(200),
     $           SECHI(200),PMAX1(200),PMAX2(200),AGCHA1(200),
     $           AGCHA2(200),PO4BEN(200),PRES1(200),PRES2(200),
     $           DFBIO1(200),DFBOD(200,3),DFCOL(200),DFNH3(200),
     $           DFNO2(200),DFORG(200),DFBIO2(200),EXPBEN(200),
     $           EXPBO1(200),EXPBOD(200,3),EXPCOL(200),EXPNH3(200),
     $           EXPNO2(200),EXPORG(200),CNBEN(200),CSAT(200),
     $           OXBEN(200),OXDELT(200),POBEN(200),CFBOD,ALG1P,
     $           ALG1N,PSP1,PSN1,PSL1,ALG2P,ALG2N,PSP2,PSN2,PSL2,
     $           OXNH3,OXNO2,OXRES1,OXRES2,OXFAC1,OXFAC2,DKBOD,
     $           DKCOL,RACIN,RACEX
C
C
      COMMON/SUN/ TL(365),SRI(365),HDL(365)
C
C
      COMMON/ATMS/QC(200),QA(200),QE(200),EQTEM(200),XQNS(200),QTOT(200)
     A,    QNS(25,10),QNA(25,10),QRNETA(25,10),QWINDA(25,10),TAA(25,10)
     B,    TAWA(25,10),APA(25,10),CLOUD(25,10),IEQTEM,JWZONE(10,2)
     C,    QRNET(200),AX(4),BX(4),ALPH(8),BETA(8),PI,WBO,DTOR
C
```

```
C
      COMMON/ICHECK/JIGNUM(200)
C
      DIMENSION C(200,14),CMASS(200,14),CSPEC(200,14)
      EQUIVALENCE (C(1,1),TEMP(1)),(CMASS(1,1),TEMPM(1))
     $            ,(CSPEC(1,1),TEMPIN(1))
C
C
C
C
      COMMON/ZONE/ CAVE(200,14),CMIN(200,14),CMAX(200,14),CX(200,14)
C
      REWIND NIU
C
C . . . . . . . . . . . . . . . . . . STEP  1
C..... DETERMINE CONTROLS AND CLOCK TIME
C
      HOURS1=FLOAT(MARK1)*DELT-DELT
      HOURS2=FLOAT(MARK2)*DELT
      KDAYS1=HOURS1/23.9999
      KDAYS2=HOURS2/23.9999
      HOURS1 = HOURS1 - FLOAT (24 * KDAYS1)
      HOURS2 = HOURS2 - FLOAT (24 * KDAYS2)
      KDAYS1=KDAYS1+1
      KDAYS2=KDAYS2+1
      WRITE(6,111) MARK1,KDAYS1,HOURS1,MARK2,KDAYS2,HOURS2
C
C . . . . . . . . . . . . . . . . . . STEP  2
C..... PRINT SUMMARY HEADINGS
C
  111 FORMAT(1H1////72H*************************     QUALITY SUMMARY    *
     ************************/
     *  55H SUMMARY STARTS AT                            SUMMARY ENDS AT/
     $   6H CYCLE,I5,6H (DAY ,I3,6H HOUR ,F5.1,13H)       CYCLE  ,
     *   I5,2H (,I3,5H DAYS,F5.1,7H HOURS)/////)
C
C . . . . . . . . . . . . . . . . . . STEP  3
C..... DETERMINE MAXIMUM, MINIMUM AND AVERAGE
C
  114 READ(NIU)  ICYCQ,((CX(J,K),K=1,NUMCON),J=JS,NJ)
      IF(ICYCQ - MARK1)114,115,118
  115 DO 117 J=1,NJ
      DO 116 K=1,NUMCON
      CAVE(J,K) = 0.5 *CX(J,K)
      CMIN(J,K) =CX(J,K)
      CMAX(J,K) =CX(J,K)
  116 CONTINUE
  117 CONTINUE
      GO TO 114
  118 DO 124 J=1,NJ
      DO 122 K=1,NUMCON
      CAVE(J,K) = CAVE(J,K) +CX(J,K)
      IF(CMIN(J,K) -CX(J,K))120,119,119
  119 CMIN(J,K) =CX(J,K)
      GO TO 122
  120 IF(CMAX(J,K)-CX(J,K)) 121,121,122
  121 CMAX(J,K)=CX(J,K)
  122 CONTINUE
  124 CONTINUE
      IF(ICYCQ-MARK2) 114,126,126
  126 DO 130 J=1,NJ
      DO 128 K=1,NUMCON
      CAVE(J,K)= CAVE(J,K)-.5*CX(J,K)
      CAVE(J,K)=CAVE(J,K)/FLOAT(MARK2-MARK1)
  128 CONTINUE
  130 CONTINUE
C
C . . . . . . . . STEP   4
C ......PRINT RESULTS
C
      DO 133 LL=1,3
      N2=5*LL
      N1=N2-4
      IF(N2 .EQ. 15) N2=14
      WRITE(6,131) ((NAME(I,N),I=1,5),N=N1,N2)
  131 FORMAT(/,12X,4(5A4,5X),5A4,/
     1    132H JUNC.      MIN.    MAX.    AVE.    MIN.    MAX.    AVE.
     2    MIN.    MAX.    AVE.    MIN.    MAX.   AVE.     MIN.    MAX.
     3    AVE.//)
      NN=0
      DO 133 J=1,NJ
      IF(NCHAN(J,1) .EQ. 0) GO TO 133
      NN=NN+1
      IF(NN .LT. 51) GO TO 135
      NN=1
      WRITE(6,131) ((NAME(I,N),I=1,5),N=N1,N2)
  135 CONTINUE
      WRITE(6,132) J,(CMIN(J,K),CMAX(J,K),CAVE(J,K),K=N1,N2)
  132 FORMAT(I4,3X,5(1X,1P3E8.2))
  133 CONTINUE
      REWIND N10
      RETURN
      END
```

Data Preparation for GBQUAL

GBQUAL requires several blocks of data to be input in the runstream for any given simulation. Some of the blocks of data originate from other computer programs. There are 3 major blocks of data that must be prepared and merged to form the full input requirements of the model. There are: (1) Physical data and quality simulation parameters and coefficients, (2) The hydrodynamic data that determines the spatial movement of water during the simulation period, (3) Meterological information. Each of these blocks of data originate from a different source and must be prepared according to GBQUAL formats. Figure D-12 illustrates the flow of data required to construct an operationally complete deck. The next section describes the formation of these blocks of data. (Since the formulation of the hydrodynamics portion is really a separate program, that portion will not be described. Figure D-13 illustrates the type of flow data required by GBQUAL.) The input format and order will be described in the same way it is read by GBQUAL. A listing of a sample deck will appear at the end.

Input Data Description

This section lists the exact format and order of all data necessary for a simulation run of GBQUAL.

FIGURE D-12
FUNCTIONAL DATA FLOW TO CREATE A DATA INPUT SET FOR GBQUAL

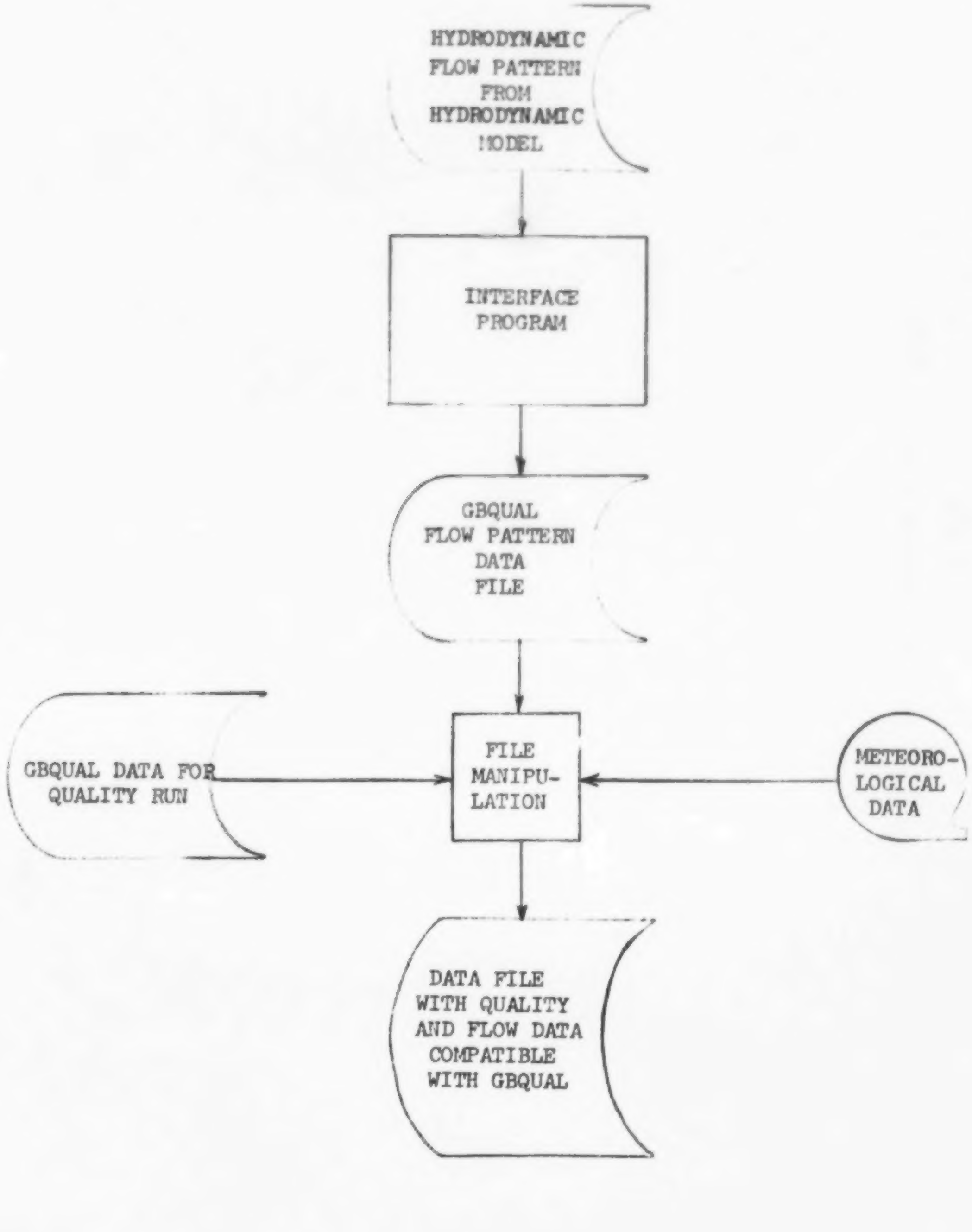
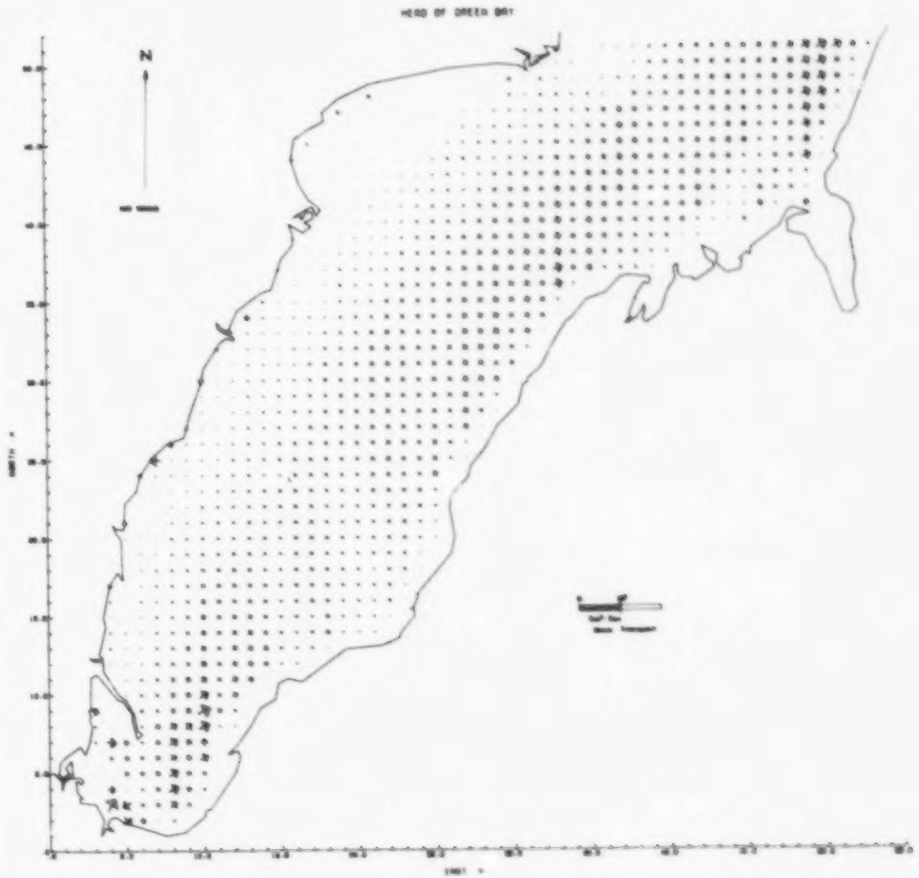

HYDRODYNAMIC FLOW PATTERN FROM HYDRODYNAMIC MODEL
INTERFACE PROGRAM
GBQUAL FLOW PATTERN DATA FILE
GBQUAL DATA FOR QUALITY RUN
FILE MANIPULATION
METEOROLOGICAL DATA
DATA FILE WITH QUALITY AND FLOW DATA COMPATIBLE WITH GBQUAL

FIGURE D-13

Typical Hydrodynamic Input to GRQUAL


HEAD OF GREEN BAY
N
5.0
10.0
15.0

System Setup Parameters

Card Type	Card Column	Format	FORTRAN Name	Description
1	--	None	IIII	Controls print interval. A value of 1 will print all junctions, 2 will print every other junction, etc.
2	1-5	I5	NJ	Number of system junctions.
	6-10	I5	NC	Number of channels
	11-20	F10.0	Delt	Time step (hours)
3	1-80	40I2	JIGNOR	NJ numbers are read here in 40I2 format. If JIGNOR(I) is set to 1 then that junction is ignored in the calculations. Set to 0 to keep it in the calculations.
4	1-5	I5	ITAPE(1)	Unit for internal scratch file.
	6-10	I5	ITAPE(2)	Hydrodynamic extract file.
	11-15	I5	ITAPE(3)	Unit to store last cycle for future restart.
	16-20	I5	ITAPE(4)	Unit for reading restart data.
		Physical Data to Describe Simulation System		
5	1-80	80A4	ALPHA(80)	A four line alpha description.
6	1-80	None	CN(NC)	Mannings N for each channel.
7	1-80	None	R(NC)	Hydraulic radius for each channel (FT).
8	1-80	None	B(NC)	Width of each channel (FT).
9	1-80	None	CLEN(NC)	Length for each channel (FT).
10	1-80	None	NJUNC (NC,1), NJUNC (NC,2)	A pair of numbers for each channel. This describes the junctions that any channel connects.
11	1-80	None	Y(NJ)	Depth of junction (FT)
12	1-80	None	ASUR(J)	Surface area of each junction in units of million sq. ft.
13	1-80	None	NCHAN (NJ, 1...8)	One card is read here for each junction. It lists the channel numbers that touch that junction.

Card Type	Card Column	Format	FORTRAN Name	Description
14	1-80	None	Q(NC)	Flow in each channel (ft^3/sec). Flows are positive if they move in the +x or +y direction.

Simulation Control Options

15	1-5	I5	INCYC	Initial quality cycle.
	6-10	I5	NQCYC	Final quality cycle.
	11-15	I5	KZOP	Option to summarize output by zones. (This is no longer used. Set to 2)
	16-20	I5	KDCOP	Control option to print depletion correction messages. Set to 2 to delete messages.
	21-25	I5	NTAG	Set equal to 1.
	26-30	I5	JS	Number of the first junction to be simulated. Usually set equal to 1
	31-35	I5	IEXC	Set equal 0

Constituent Selection

(To simulate a given group, set its ISWTCH value to zero)

16	1-5	I5	ISWTCH(1)	Coliforms
	6-10	I5	ISWTCH(2)	For the group (Org-N, NH_3-N, NO_2-N, NO_3-N, PO_4-P and Algae 1)
	11-15	I5	ISWTCH(3)	Algae 2
	16-20	I5	ISWTCH(4)	Total nitrogen as a conservative
	21-25	I5	ISWTCH(5)	BOD and DO
	26-30	I5	ISWTCH(6)	Temperature

Print Control Options

17	1-5	I5	IPRT	Initial cycle for quality print out.
	6-10	I5	NQPRT	Number of time steps between prints.
	11-15	I5	IWRITE	Initial cycle for storage of data for quality summary.
	16-20	I5	IWRINT	Number of time steps for quality summary print.
	21-25	I5	NOPRT	Number of junctions printed in each quality print.

Printing Order

Card Type	Card Column	Format	FORTRAN Name	Description
18	1-70	14I5	JPRT (NOPRT)	This array lists the printing order (by junction) of the quality print out.

Meteorological Data

(Card Types 19 through 21 contain data required to compute diurnal temperature fluctuations. If temperature is not being simulated, card types 19-21 can be deleted.)

19	Data limits, 1 card			
	1-5	I5	NWZONE	Number of weather zones.
	6-10	I5	NPTS	Number of data points used to describe one day's weather.
	11-15	I5	NQCSM	Number of quality time steps between the start of the quality simulation and midnight.
	16-20	I5	NRCALC	Net radiation calculation switch; if NRCALC = 1, net radiation will be calculated from sun angle and cloud cover.
	21-25	I5	IEQTEM	Equilibrium temperature calculation switch, if IEQTEM = 1, the equilibrium temperature will be calculated.
	26-30	I5	IDAY	Day of the year.

Repeat Card Types 20 and 21 for NWZONE weather zones (one set per weather zone).

Weather zone general data, 2 cards

20	1-5	I5	JWZONE(I,1)	First junction in weather zone I.
	6-10	I5	JWZONE(I,2)	Second junction in weather zone I.
	11-20	F10.0	XLAT	Latitude of the study area, degrees.
	21-30	F10.0	XLON	Longitude of the study area, degrees.
	31-40	F10.0	EPS	Site location code: -1. = West longitude +1. = East longitude
	41-50	F10.0	TURB	Atmospheric turbidity factor. Values range from 2.0 for clear unpolluted atmosphere to 5.0 for highly polluted atmosphere.

Card Type	Card Column	Format	FORTRAN Name	Description
	51-60	F10.0	AA	Evaporation Coefficient "a" (usually 0.0).
	61-70	F10.0	BB	Evaporation coefficient "b" (usually 1.5 x 10^{-9}).
21	Atmospheric data, NPTS cards (one card per weather data point)			
	1-10	F10.0	QRNETA	Net incoming radiation (leave blank if NRCALC=1) kcal/sq. Meter/sec.
	11-20	F10.0	UWINDA	Wind speed, meters/sec.
	21-30	F10.0	CLOUD	Cloud cover, fraction.
	31-40	F10.0	TAA	Dry bulb temperature, °C.
	41-50	F10.0	TAWA	Wet bulb temperature, °C.
	51-60	F10.0	APA	Atmospheric pressure, millibars.

Solar Intensity

(This is needed only if algae is simulated. There must be 1 card for each day of simulation including partial days.)

22	1-10	F10.0	TL	Total amount of incident solar radiation in langleys.
	11-20	F10.0	SRI	Hour of sunrise
	21-30	F10.0	HDL	Number of hours of day light.

Chemical, Physical and Biologic Coefficients

(Card types 23 through 27 contain the reaction rate constants and other coefficients for those constituents being modeled.)

Spatially varying coefficients

(Repeat Card Type 23 as necessary to input spatially varying coefficients over the total network. (5 sets of junction and coefficient values per card for each of the listed coefficients.) Terminate each set of coefficient data with one blank set of data).

For each coefficient in the list below:

23	1-4	I4	JUN1(1)	First junction for which the coefficient applies.
	5-8	I4	JUN2(1)	Last junction for which the coefficient applies.

Card Type	Card Column	Format	FORTRAN Name	Description
	9-16	F8.0	COEF(1)	Coefficient value
	⋮	⋮	⋮	
	65-68	I4	JUN1(5)	Five sets of junctions and coefficients per card
	69-72	I4	JUN1(5)	
	73-80	F8.0	COEF(5)	

The following coefficients are input in the above manner and in the order listed.

FORTRAN Name	Coefficient	Data Units (Decay rates are all base e)
REOX	Reaeration (if reaeration is to be calculated set COEF(1) = -1.)	day^{-1}
COLDK(1)	Coliform bacteria dieoff rate	day^{-1}
BODDK(1)	Coliform bacteria dieoff rate	day^{-1}
BODDK(2)	BOD decay rate	day^{-1}
BODDK(3)	BOD decay rate	day^{-1}
CNH3DK	Ammonia decay rate	day^{-1}
CNO2DK	Nitrite decay rate	day^{-1}
CORGAK	Organic nitrogen decay rate	day^{-1}
AGSNK1	Algae sink rates	ft/day
AGSNK2	Algae sink rates	ft/day
PRES1	Algae respiration rate	day^{-1}
PRES2	Algae respiration rate	day^{-1}
POSINK	Phosphate precipitation rate	day^{-1}
PO4BEN	Source rate of phosphate	$mg/ft^2/day$
OXYBEN	Benthic uptake of oxygen	$mg/ft^2/day$
CNHBEN	Release of ammonia from sediments	$mg/ft^2/day$
SECHI	Secchi disc depth	feet
PMAX1	Algae max. specific growth rate	day^{-1}
PMAX2	Algae max. specific growth rate	day^{-1}
AGCHA1	Ratio of chlorophyll a to algae biomass(mg/mg)	decimal
AGCHA2	Ratio of chlorophyll a to algae biomass(mg/mg)	decimal
DIFFK	Eddy diffusion rate	ft^2/sec

Card Type	Card Column	Format	FORTRAN Name	Description
24	Algae related coefficients, 2 cards. Repeat Card 24 for the second algae type. Both cards are required.			
	1-10	F10.0	ALGIP	Phosphorus content of Algae -1, fraction of total biomass.
	11-20	F10.0	ALGIN	Nitrogen content of Algae -1, fraction of total biomass.
	21-30	F10.0	PSP1	Phosphate half-saturation constant, mg/l as phosphorus.
	31-40	F10.0	PSN1	Nitrogen half-saturation constant, mg/l.
	41-50	F10.0	PSL1	Light saturation constant, langleys/hour.

Card Type	Card Column	Format	FORTRAN Name	Description
25	Spatially invariant coefficients: stoichiometric equivalences, 1 card			
	1-10	F10.0	OXNO2	Stoichiometric equivalence between oxygen and nitrite, mg/mg.
	11-20	F10.0	OXNH3	Stoichiometric equivalence between oxygen and ammonia, mg/mg.
	21-30	F10.0	OXRES1	Stochiometric equivalence between respiration and Chl-a.
	31-40	F10.0	OXRES2	Oxygen produced by photosynthesis per mg of Chl-a.
	41-50	F10.0	OXFAC1	Oxygen produced by photosynthesis per mg of Chl-a.
	51-60	F10.0	OXFAC2	Oxygen produced by photosynthesis per mg of Chl-a.
26	Algae related coefficients, continued, 1 card			
	1-10	F10.0	RACIN	Ratio of chlorophyll a to algae biomass in all inflows.
	11-20	F10.0	RACEX	Ratio of chlorophyll a to algae biomass at the exchange junction.

Temperature Correction Coefficients

Card Type	Card Column	Format	FORTRAN Name	Description
27	1-10	F10.0	AQ10(1)	Three coeff. for temperature correction for each temperature adjusted coefficient.
	11-20	F10.0	AQ10(2)	
	21-30	F10.0	AQ10(3)	

AQ10 1 thru 3 are used in the following equation:

- = AQ10(1) + AQ10(2)* T + AQ10(3)* T* T

where T is the temperature in °C.

Card 27 is read for each of the following list in the given order:

Decay Coefficient

1. Coliform decay
2. BOD-1 decay
3. BOD-2 decay
4. BOD-3 decay
5. Ammonia decay

Card Type	Card Column	Format	FORTRAN Name	Description

6. Nitrite decay
7. Benthic oxygen demand
8. Organic nitrogen decay
9. Alg-1 activity
10. Alg-2 activity

Input Data cards 28-30 and 32 require data for each of 14 constituents. The following data order must be used to insure that the data are stored in the correct positions in the storage array.

Constituent No.	Constituent
1	Temperature
2	Dissolved oxygen
3	Ultimate biochemical oxygen demand (BOD-1)
4	Ultimate biochemical oxygen demand (BOD-2)
5	Ultimate biochemical oxygen demand (BOD-3)
6	Organic nitrogen
7	Ammonia nitrogen
8	Nitrite nitrogen
9	Nitrate nitrogen
10	Phosphate phosphorus
11	Algae-1
12	Algae-2
13	Coliforms
14	Total nitrogen

Maximum Allowable Concentrations

Card Type 28 sets maximum concentrations for all constituents. Simulation terminates when any of these values are exceeded.

28	Concentrations, 2 cards			
	1-10	F10.0	CLIMIT(I)	Maximum allowable concentration for the fourteen constituents. Two cards are required with eight values on the first and six on the second.
	71-80	F10.0	CLIMIT(I+6)	

If this is a restart deck then skip card type 29 and 30. If temperature is not being simulated then do card type 31. If this is not a restart deck then do Card type 29 and 30 and skip 31.

Initial Concentrations

Repeat Card Types 29 and 30 until all initial quality groups are given. Terminate data with two blank cards.

Initial quality group concentrations, 1 card.

29	1-5	I5	J1	First junction of an initial quality group.

Card Type	Card Column	Format	FORTRAN Name	Description
	6-10	I5	J2	Last junction of an initial quality group.
	11-20	F10.0	CTEMP(1)	Temporary read array for entering the initial concentration of the first seven constituents.
	71-80	F10.0	CTEMP(7)	
30	Initial quality group concentrations, continued, 1 card			
	1-10	F10.0	CTEMP(8)	Temporary read array for entering the initial concentration of the last seven constituents.
	71-80	F10.0	CTEMP(14)	

Initial Temperature for Restart

(Do only if temperature is not being simulated and this is a restart deck. Use the same format as for card type 23.)

31	1-4	I4	JUNC1(1)	First junction for which the temperature applies.
	5-8	I4	JUNC2(1)	Last junction for which the temperature applies.
	9-16	F8.0	COEF(1)	Temperatures.
	65-68	I4	JUNC1(5)	Five sets of junctions and initial temperatures per card
	69-72	I4	JUNC1(5)	
	73-80	F8.0	COEF(5)	

One blank set should appear to terminate this input.

Inflow/Outflow Quality

Repeat Card Types 32, 33 and 34 until all junctions with inflow/outflow are listed. Terminate with three blank cards.

32	Inflow/outflow description, 1 card			
	1-80	20A4	NAME	Description of the inflow or outflow
33	Inflow/outflow rate and concentrations at junction, 1 card			
	1-80	I8	JJ	Junction number
	9-16	F8.0	QQ	Inflow or outflow rate, inflows are positive and outflows are negative.
	17-24	F8.0	CTEMP(1)	Temporary read array for entering the inflow concentration of the first eight constituents.
	73-80	F8.0	CTEMP(8)	Leave blank if this is an outflow.
34	Inflow concentration, continued, 1 card			
	1-16	16X		Blank
	17-24	F8.0	CTEMP(9)	Temporary read array for entering the inflow concentration of the last six constituents. Leave blank if outflow.
	65-72	F8.0	CTEMP(15)	

Quality Adjustment Factors

(Card Types 35 and 36 contain initial quality concentration adjustment factors by constituent for areas described by given junctions.)

Repeat Card Types 35 and 36 for each constituent (I). If a constituent is not going to be altered, set NGROUP(I)=0 and card 36 can be omitted. If no factors are going to be applied to the remaining constituents, set NGROUP=-1 and do not repeat for each constituent.

Card Type	Card Column	Format	FORTRAN Name	Description
35	Data limit, 1 card			
	1-5	I5	NGROUP(I)	The number of groups of junction numbers for which it is desired to increment the initial concentrations of constituent I which was previously read as input. There is no limit (up to NJ) to the number of junctions. comprising a group but the numbers must be consecutive. Max. number of groups = 10.
36	Adjustment factors by constituent and group, NGROUP/5 cards (5 groups per card)			
	1-5	F5.0	FACTR(I,K)	Multiplication factor to be applied to the initial concentration of constituent I at those junctions in group K.
	6-10	I5	NJSTRT (I,K)	The first (lowest) junction number in the sequence of junctions comprising group K for constituent I.
	11-15	I5	NJSTOP (I,K)	The final (highest) junction number in the sequence of junctions comprising group K for constituent I.
	61-65	F5.0	FACTR (I, K+4)	Five junction groups per card for constituent I.
	66-70	I5	NJSTRT (I, K+4)	
	71-75	I5	NJSTOP (I, K+4)	

Boundary Junction Quality

(Card Types 37 through 38 describe constituent concentrations at the seaward boundary of the system throughout the tidal cycle.)

37	Control options, 1 card			
	1-5	I5	KBOP(1)	Control option for specifying concentrations of each constituent at the boundary. If the concentration is constant over all cycles, KBOP=1; if variable, leave blank.
	.	.		
	.	.		
	.	.		
	71-75	I5	KBOP(15)	

Use one card with one concentration (CIN(I,1)) for each constituent (I). If the constituent is not to be modeled, set CIN(I,1)=-1. All fourteen constituents must be listed.

Card Type	Card Column	Format	FORTRAN Name	Description
38	Boundary junction concentration			
	1-10	F10.0	CIN(I,J)	Boundary junction concentration at each time step (J) in the tidal cycle.
	71-80	F10.0	CIN(I,J+6)	

Output Description

The Quality Program will produce two types of output: (1) printed reports, or (2) a binary (file/tape) restart data file.

Printed Reports

Printed output includes: echo reports of much of the input data and a report at selected time intervals of the quality at specified junctions. The use of various printout options also allows printing of a summary of all water quality parameters at each junctions over a specified number of cycles. This report gives the minimum, maximum and average value for any constituent in each requested junction. It is possible to use this output form as a check on the steady state of the system. If a given run is given steady hydrodynamics and steady inflowing quality, then a steady state in the system will eventually be attained. This can be checked by comparing the maximum versus minimum value of a constituent (particularly a conservative) during the summary period. An example input deck and output reports for a typical model run appear in the next section.

The binary restart file is used to feed the final conditions of a completed run into the next run as the initial conditions. In this way, the user can keep continuity between runs and still have flexibility in updating inflowing quantity and quality and/or temperature of the system. Depending on the computer system the restart file can be written to a tape or a mass storage file. It is also possible to direct this output to a card punch and develope the restart information in the form of punched cards.

DATA SET FOR GBQUAL

```
  1
  87  182  6.0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0
0 0 0 0 0 0 1
  10     0   29    28     0
  GREEN BAY --- WINTER CONDITION --- JAN 1 TO MAR 15      ---
  FOX RIVER INFLOW --2403 CFS  NO WIND MODEL
   HYDRODYNAMICS FROM K. LEE
   FOX RIVER IS ONLY INFLOW
.03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03
.03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03
.03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03
.03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03
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.03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03
.03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03
.03 .03
    4.90      5.90      6.90      6.90      9.90     10.40      8.65      8.90     10.15     11.65
   10.90     14.90     14.90      6.40     23.23     21.23      4.90      7.40     10.40     11.90
   11.90     24.40     24.07     22.65     24.90      8.15     10.40     24.23     11.15     12.90
   10.65      9.90     11.90     26.23      5.90      8.90     29.27     10.90     10.90     11.40
    7.40     27.40     28.40     15.90      8.90     32.60     29.[illegible]     18.73     17.15      7.40
   41.23     34.40     17.57     10.40     16.65     22.23     20.90     11.90     11.40      9.40
   36.70     20.90     22.40     11.02      8.65     15.90     19.40     21.73     16.73     24.15
   28.73     17.90     18.40     17.23     32.23     35.40     10.90     24.40     23.77     18.22
   16.30      5.90     37.40     39.65     33.02     29.40      7.70     10.07     16.77     13.90
   15.40     24.02     27.15     11.67     24.07     13.80     16.15     17.57     29.20     42.40
   40.90     33.07      9.15     18.80      8.90     17.90     52.07      8.65     34.40     32.90
   16.83     18.80     20.40     29.27     46.70     39.21     37.40     49.90     52.69     42.83
   54.90     46.52     18.00     18.30      8.57     50.90     40.40     25.80     19.55     11.65
    5.40      8.65     17.73     21.65     23.40     13.27     59.30     65.65     52.23     59.23
   35.80     40.40      7.84     22.34      3.28     21.67      4.34     20.15     14.68      8.73
   56.73     28.40     50.32     71.30     62.50     73.02     60.40     54.30     24.00     48.90
   15.36      3.02     38.15     29.70     17.40      9.07     14.15     52.15     60.90     28.70
   14.15     15.90     54.67     24.55     38.90     37.52     81.76     85.27     14.52     81.50
   99.90     51.92
   3286.     3286.     3286.     3286.     3286.     3286.     6572.     3286.     6572.     6572.
   3286.     6572.     3286.     3286.     9858.     9858.     3286.     3286.     3286.     6572.
   3286.     6572.     9858.     6572.     9858.     6572.     3286.     9858.     6572.     3286.
   6572.     3286.     3286.     9858.     6572.     3286.    13144.     6572.     3286.     6572.
   3286.     9858.    13144.     6572.     3286.    16430.     6572.     9858.     6572.     3286.
   9858.    13144.     9858.     3286.     6572.     9858.     6572.     3286.     3286.     6572.
  16430.     9858.     3286.    13144.     6572.     9858.     6572.     9858.     9858.     6572.
   9858.     9858.     3286.     9858.     9858.    13144.     3286.     6572.    13144.    13144.
   6572.     6572.     6572.    13144.    13144.     9858.    19716.     9858.    13144.     6572.
   9858.    13144.     6572.     9858.     9858.     6572.    13144.     9858.    16430.     6572.
   6572.     9858.     6572.    16430.     6572.     6572.     9858.    13144.     3286.     3286.
   9858.     6572.     3286.    13144.    23002.    26288.     9858.     3286.    23002.    23002.
   9858.    13144.     9858.     6572.     9858.     6572.     3286.     6572.     6572.    13144.
   6572.     6572.     9858.     6572.    13144.    13144.    16430.    13144.     9858.     9858.
   6572.     6572.     3286.     3286.     3286.     9858.     3286.     6572.    16430.     9858.
  19716.     9858.    19716.    16430.    16430.    13144.     9858.    16430.     9858.     3286.
   9858.     6572.    13144.    16430.     3286.     9858.     6572.     6572.     9858.     3286.
  6572.   9858.   9858.   6572.   6572.  13144.  23002.  13144.  13144.  32860.
  9858.  13144.
  4929.   3286.   6572.   3286.   3286.   6572.   3286.   6572.   3286.   3286.
  4929.   8215.   8215.   6572.   9858.   9858.   3286.   9858.   3286.   3286.
  8215.   9858.  13144.   9858.  14787.   3286.   6572.  11501.   3286.   6572.
  4929.   6572.   6572.  11501.   3286.   4929.  13144.   4929.   4929.   6572.
  6572.  13144.  16430.   8215.   6572.  13144.  11501.   6572.   6572.   8215.
 13144.  16430.   8215.   8215.   6572.   8215.   9858.   8215.   6572.   8215.
 13144.   9858.   8215.   9858.   8215.  14787.   9858.   8215.   9858.   9858.
 21359.   9858.   9858.   6572.  11501.  16430.  16430.  13144.   8215.   8215.
  6572.  13144.  13144.  26288.   9858.   9858.   6572.  16430.   9858.   9858.
 23002.   9858.  14787.   4929.   4929.  14787.   9858.  21359.  11501.   9858.
 21359.   6572.   8215.  11501.  13144.  14787.  24645.   8215.  16430.  16430.
  4929.  16430.   9858.  31217.  11501.  11501.  19716.  13144.  13144.   9858.
 23002.   9858.   6572.  11501.  11501.  18073.  11501.   6572.   8215.  11501.
  4929.   9858.   9858.  11501.   9858.  23002.  21359.  18073.  13144.  21359.
  8215.  19716.   9858.  18073.  11501.   9858.   9858.   9858.   8215.   9858.
 18073.   9858.  23002.  26288.  16430.  23002.  14787.  19716.  14787.  19716.
  6572.   9858.  13144.  13144.  13144.  11501.  13144.  21359.  14787.   6572.
 11501.  11501.   8215.  13144.  18073.  26288.  23002.  11501.   8215.  16430.
 13144.   8215.
  1   8   1  10   1   2   2  10   2  11   2   5   3   2   3   4   4   5   5  11
  5   6  31  29  31   7   8  10  29  30   7   9  10  13  10  11  11  13  11  14
 11   6   9  32  30   9  30  32  32  12  13  17  13  14  32  34  14  18  14  15
  6  15  17  18  18  15  12  16  17  20  17  21  16  19  18  21  23  26  15  22
 20  21  16  37  37  24  21  22  22  23  19  24  12  19  21  25  22  26  23  27
 47  51  47  84  25  29  28  25  26  27  26  30  25  26  28  31  28  29  31  36
 84  51  27  32  30  27  67  60  36   7   7  40  40   9   9  41  86  60  41  12
 12  44  29   7  32  33  33  34  44  19  19  47  67  86  34  35  35  37  37  38
 38  42  36  39  47  24  24  51  24  45  24  42  39  40  40  46  40  41  46  41
 41  48  41  44  42  45  42  43  45  43  43  49  48  44  44  55  44  47  51  45
 45  52  45  49  46  48  55  84  84  56  84  59  52  85  48  55  49  52  49  53
 49  50  50  53  59  51  51  60  51  52  60  85  85  76  85  73  85  61  52  53
 53  61  53  56  53  54  54  56  55  58  56  61  56  62  56  57  57  62  58  59
 58  67  59  67  59  60  60  76  34  16  60  72  61  73  61  68  61  62  62  68
 62  63  63  68  63  64  64  68  64  65  64  69  65  69  69  66  66  70  66  72
 73  68   9  12  68  82  68  80  68  69  69  80  69  70  70  60  70  71  71  80
 71  75  65  66  76  73  73  78  74  73  72  74  74  76  80  75  75  81  75  77
 72  76  76  74  81  77  77  63  78  82  82  80  80  81  81  83  82  87  80  87
 81  67  83  87
    2.89     7.91     6.40     7.41     9.91     7.91    14.57     1.74    22.54     3.90
    9.91    25.82     6.40    10.37    10.50    25.56     5.54     8.89    30.41     3.28
   13.58    11.38     1.71    31.50    16.40    17.91    13.91     7.41    16.11    21.92
   12.07    22.41    11.22    20.64    16.90     4.89    24.90    14.40     3.22    12.07
   18.31    23.39    14.04    24.11    33.50     7.35    34.61     7.32    29.04    21.65
   39.66    44.85    43.34    19.91    11.58    39.24    24.57     4.86    13.78    23.16
   56.89    55.45    39.07    21.69    13.44    12.07     3.48    60.76    65.19    46.16
   40.91     9.15    38.84     7.58    65.91    20.64    39.57    14.01    16.40    77.07
   90.29    12.27    51.90    25.29    44.72     7.45    71.19
   21.56    21.56    21.56    21.56    21.56    32.34    97.03    53.91   161.72    21.56
   32.34   161.72    21.56    21.56    53.91   129.37    32.34    21.56   215.62    97.03
   64.69    43.12    21.56   301.87    64.69    64.69    64.69    21.56    97.03    97.03
   64.69   129.37    32.34   129.37    86.25    43.12   129.37    43.12    86.25   194.06
  194.06    64.69    75.47   258.75   129.37    97.03   215.62   183.28    64.69    43.12
  388.12   301.87   226.40    43.12   161.72   129.37    32.34   161.72    86.25   431.29
  377.34    97.03    43.12    43.12    32.34    75.47    75.47   646.87   215.62   161.72
   97.03   172.50   323.43    97.03    64.69   129.37    64.69   107.81   161.72   970.30
```

```
226.40  237.18  140.15  215.62  258.75  107.81  226.40
  1   2   3   0   0   0   0   0
  3   4   5   6   7   0   0   0
  7   8   0   0   0   0   0   0
  8   9   0   0   0   0   0   0
  6  10  11   9   0   0   0   0
 11  21  31   0   0   0   0   0
 13  65  66  16  72   0   0   0
  1  14   0   0   0   0   0   0
 16  67  23  68 152  22   0   0
  2  14  17  18   4   0   0   0
  5  18  19  20  21  10   0   0
 25 152  70  71  47  34   0   0
 17  19  26  27   0   0   0   0
 20  27  29  30   0   0   0   0
 31  30  33  40   0   0   0   0
135  34  37  42   0   0   0   0
 26  35  36  32   0   0   0   0
 29  32  38  33   0   0   0   0
 37  47  75  46  76   0   0   0
 35  41   0   0   0   0   0   0
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 45  50  39   0   0   0   0   0
 43  46  63  84  85  86   0   0
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 49  57  56  55  39   0   0   0
 50  55  63  62   0   0   0   0
 54  59  58   0   0   0   0   0
 53  59  12  72  15   0   0   0
 56  15  23  24  63   0   0   0
 58  60  12  13   0   0   0   0
 24  22  62  25  28  73   0   0
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 74  28 135  78   0   0   0   0
 76  79   0   0   0   0   0   0
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 80  81   0   0   0   0   0   0
 82  87   0   0   0   0   0   0
 66  87  88  89  67   0   0   0
 68  89  90  91  92  70   0   0
 81  86  93  94   0   0   0   0
 94  95  96   0   0   0   0   0
 71  92  97  98  99  75   0   0
 93  85 100 101 102  95   0   0
 88  90 103   0   0   0   0   0
 76  99  51  52  63   0   0   0
 91 103  97 108   0   0   0   0
 96 102 109 110 111   0   0   0
111 112   0   0   0   0   0   0
 64 113 114 115 100  51  61   0
101 115 120 109 107   0   0   0
112 120 121 122 123 110   0   0
123 124   0   0   0   0   0   0
 98 108 125 104   0   0   0   0
124 122 126 127 128   0   0   0
```

```
 126 129   0   0   0   0   0   0
 125 105 130 131   0   0   0   0
 106 130 132 133 113   0   0   0
 114 135 136 134 116  64  69   0
 121 119 137 138 139 126   0   0
 129 127 139 140 141   0   0   0
 141 142 143   0   0   0   0   0
 143 144 145 146   0   0   0   0
 145 162 147   0   0   0   0   0
 162 148 149   0   0   0   0   0
 132 131  77  64   0   0   0   0
 142 140 138 151 144 153 154 155
 146 147 155 156 157 148   0   0
 149 157 158 159   0   0   0   0
 159 160 161   0   0   0   0   0
 136 150 171 166   0   0   0   0
 137 118 163 165 164 151   0   0
 172 166 167 165   0   0   0   0
 161 168 169 170   0   0   0   0
 117 134 171 172 163   0   0   0
 170 173 174   0   0   0   0   0
 164 167 175   0   0   0   0   0
   0   0   0   0   0   0   0   0
 160 158 156 154 176 177 168 180
 169 177 178 173 181   0   0   0
 153 175 176 179   0   0   0   0
 174 178 162   0   0   0   0   0
  52 104  61 105 106   0   0   0
 107 116 117 118 119   0   0   0
  77 150  69   0   0   0   0   0
 179 180 181 182   0   0   0   0
  1397.430   563.476   442.243    78.559    90.752     3.687  -269.244   269.244
   269.244   214.159    58.772   -78.737    11.159  1397.430   266.846   180.592
  1074.433   965.032   650.950   435.058   183.935   265.538   340.050   376.787
   293.507  1305.327   420.055   912.302   616.004   239.109   242.708   384.781
   276.262   352.708   371.126   549.418   531.276   722.523   343.871   760.078
   371.128   642.227   782.866   622.147   484.667   578.466   223.355  1020.923
   897.550   140.796   176.027   152.920   772.184   -82.756   699.903   707.510
   165.984    88.456    -5.700   156.034   114.761  1098.218   257.519    12.562
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   485.600   117.584   173.897   638.356   483.949   412.927   117.584    47.129
   239.781   -21.607   -75.386   214.959   540.942   357.585   434.236   791.821
   -33.919    26.099    59.716   230.052   454.508   366.199    68.736      .202
     4.263    34.099   489.195    27.270   218.579   256.568   680.873   680.873
     7.438    14.185   692.345   -66.294   -43.495    43.295   423.101   876.238
   162.968   838.075   814.635   814.635    53.166   333.042   592.609   727.059
   727.059    47.395    10.035    -4.619    78.674    84.502   820.794    16.743
  -302.097   566.911   654.298   966.068  1007.898   739.801   268.097   138.775
    -3.481   132.803      .043   303.804   300.281    63.324   359.480   331.538
 -1464.381  1336.943  2918.473  1312.256  1435.257  1292.103   443.435   443.435
      .000    -3.523    97.157  -517.112     4.014    22.494    19.903   853.465
   853.465      .000    57.572     1.423  1268.998  1268.998  -497.209  -864.871
  3235.125  2098.832 -1116.719  -568.723   720.761  3367.829
  201  500    2    2    1    1    0
    1    0    0    0    0    1
  238   40  201   40   65
  1    2    3    4    5    6    8   10   11   13   14   15   17   18
 20   21   22   23   25   26   27   28   29   30   31   32   33   34
 35   36    7    9   12   16   37   38   39   40   41   19   24   42
 43   44   45   46   47   48   49   50   51   52   53   54   55   84
 56   57   58   59   60   85   61   62   63   64   65   66   67   68
 69   70   71   86   72   73   74   75   76   77   78   80   81   82
 83
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
    100.0        7.0      10.0
```

```
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
      100.0       7.0       10.0
   1  27      .00  28  28     .40  29  87      .00
   1  87     0.50
   1  87      .42
   1  87     .037
   1  87     .006
   1  87      .05
   1  87     1.50
   1  87    0.080
   1  87      0.5
   1  87      0.5
   1  87      0.1
   1  87      0.1
   1  87     0.05
   1  87      0.0
   1   2      40.   2   6     15.   7   8     10.   9   9     10.  10  11     40.
  12  12      15.  13  15     25.  16  16     15.  17  18     25.  19  20     15.
  21  23      20.  24  27     15.  28  29     10.  30  30     15.  31  31     10.
  32  35      15.  36  36     10.  37  38     15.  39  41     10.  42  43     15.
  44  44      10.  45  45     15.  46  46     10.  49  50     15.  51  87     10.

   1  87      0.0
   1  87      0.5
   1  87     1.00
   1  87      1.0
   1  87      .05
   1  87      .05
   1  87      0.0
     0.012       0.08       .03       0.3      7.8
     0.012       0.08       .03   0.00001      7.8
     1.2      3.4    .025         .025      .25       .25
      0.05       0.05
     1.047
```

```
 1.140098 -0.003856
 1.140098 -0.003856
 1.140098 -0.003856
1.2134705-0.0107843
1.2134705-0.0107843
1.1       -0.00175
    1.047
    1.047
    1.047
      80.       80.       80.       80.       80.     20.            10.        2.
      15.        5.       0.2       0.2      10.0      20.0
  1  87  2.0001
  FOX RIVER INFLOW
     1 2403.10       2.       10.       2.0       4.      30.     .500      .50      .01
                   0.2       .03      .005      .005      0.      1.21
  OUT FLOW JUNCTION
    87-2403.10



 -1
  1    1    1    1    1    1    1    1    1    1    1    1
      2.
     10.
     10.
     16.
     87.
     .50
     .50
     .01
     .20
     .03
    .005
    .005
    -1.0
    1.21
```

APPENDIX E

HYDRODYNAMIC MODELLING

The circulation patterns used in the water quality simulation in this report were generated by using a separated hydrodynamic model developed independently. This appendix provides a brief presentation of the formulation and the structure used in the hydrodynamic model. The broad objective of the model was to investigate the hydrodynamic response of Green Bay to the meteorological input at the surface, to the effects at open boundaries in the Bay, and to the river inflows. The flow in the Bay is affected by the boundary conditions at the shore and the bottom as well as the open ends. The model is designed to calculate Bay-level disturbance and water circulation generated by wind fields over the region in a numerically reproduced combined river-shallow sea system.

Fundamental Hydrodynamic Equations

The flow in the Bay is basically unsteady and three dimensional. The equations which describe the circulation in the Bay can be written in the form of a set of nonlinear partial differential equations for conservation of mass and conservation of momentum in the Eulerian form. The Cartesian coordinate system is chosen where X and Y are taken in a horizontal plane of the undisturbed surface with X eastward and Y northward and Z is vertically upward. The basic governing equations for a three dimensional model and two-dimensional model for an estuary were thoroughly discussed and derived by Pritchard (1971). Considering Green Bay, a fresh water estuary, one can assume a two-dimensional model with the following equations:

$$\frac{\partial h}{\partial t} + \frac{\partial}{\partial x}(HU) + \frac{\partial}{\partial y}(HV) = 0 \tag{1}$$

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} = -\frac{1}{\rho}\frac{\partial P_a}{\partial x} - g\frac{\partial h}{\partial x} + fV + \frac{1}{H}(\tau_{wx} - \tau_{Bx}) \tag{2}$$

$$\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} = -\frac{1}{\rho}\frac{\partial P_a}{\partial y} - g\frac{\partial h}{\partial y} - fU + \frac{1}{H}(\tau_{wy} - \tau_{By}) \tag{3}$$

where the notation is as follows:

h = elevation of water surface

f = Coriolis parameter

P_a = surface atmospheric pressure

ρ = vertical mean water density

H = bottom elevation ($z = -H$)

g = acceleration due to gravity

(U,V) = vertical mean horizontal velocity averaged from the water surface to the bottom in (x,y) direction

(τ_{wx}, τ_{wy}) = surface wind stress in (x,y) direction

(τ_{Bx}, τ_{By}) = bottom frictional stress in (x,y) direction

These equations are similar to those used by Leendertse (1970) in his work on the Jamaica Bay simulation.

Surface and Wind Stress and Bottom Frictional Stress

The bottom frictional stress, τ_{Bx} and τ_{By}, is expressed in the form:

$$\tau_{Bx} = \rho g U \left[\frac{\sqrt{U^2 + V^2}}{C^2} \right] \tag{4}$$

$$\tau_{By} = \rho g V \left[\frac{\sqrt{U^2 + V^2}}{C^2} \right] \tag{5}$$

where C is the Chezy coefficient. The Chezy coefficient depends on the roughness of the bottom and the depth of the water. The Chezy coefficient may be related to Manning's roughness coefficient, n, by the familiar formula:

$$C = (1.49/n)\ H^{1/6} \tag{6}$$

The Chezy coefficient in the formula has the units $ft^{1/2}/sec$ and H is in ft. An appropriate unit conversion should be made because the model computation is made in the cgs system. The value, n, changes as the type of bottom varies.

The wind stress at the water surface is approximated by assuming the validity of a logrithmic distribution of wind velocity with height. Therefore:

$$\tau_{wx} = C_w \rho_a U_w \ U_w \tag{7}$$

$$\tau_{wy} = C_w \rho_a V_w \ V_w \tag{8}$$

where ρ_a is the air density, U_w and V_w are the wind velocity compontents measures at a height 10 meters above the water surface and C_{wx} is the wind stress coefficient. Wu (1969) suggested two approximate formulas for the wind stress coefficient based upon the compiled data of thirty observations. $C_w = 0.5$ (wind speed) $^{1/2}$ for light wind, 1m/sec<(wind speed)<15m/sec. $C_w = 2.6 \times 10^{-3}$ for strong winds (>15m/sec). For breeze, $C_w = 1.25 \times 10^{-3}/(\text{wind speed})^{1/5}$.

Numerical Scheme

A set of finite difference equations are used to replace the governing differential equations. The numerical scheme used is a space-staggered scheme where velocities, water levels, and depths are described at different grid points. Figure E-1 illustrates the scheme. The water level h is described at integer values of j and k, the velocity U is described at integer and one half values of j and integer values of k, and the velocity V is described at integer values of j and integer and one half values of k. The basic scheme is widely used by many investigators (Platzman, 1959; Heaps, 1969; and Leendertse, 1970). The scheme has the advantage that in the equation for the variable operated upon in time, there is a centrally located spacial derivative for the linear term. A detailed mathematical formulation can be found in Lee (1974). The operation consists of two successive time intervals. The first time level is taken from time n to time $n+\frac{1}{2}$ and the second time level is taken from time $n+\frac{1}{2}$ to n+1. The field variables $h^{(n+\frac{1}{2})}$, $U^{n+\frac{1}{2}}$ and $V^{n+\frac{1}{2}}$ are obtained from $h^{(n)}$, $U^{(n)}$ and $V^{(n)}$. The process involves solving h and U implicitly and V explicitly. In the second time level, the variables $h^{n+\frac{1}{2}}$, $U^{n+\frac{1}{2}}$ and $V^{n+\frac{1}{2}}$ are used to compute h^{n+1}, U^{n+1}, and V^{n+1}. The operation is implicit in h and V and explicit in U.

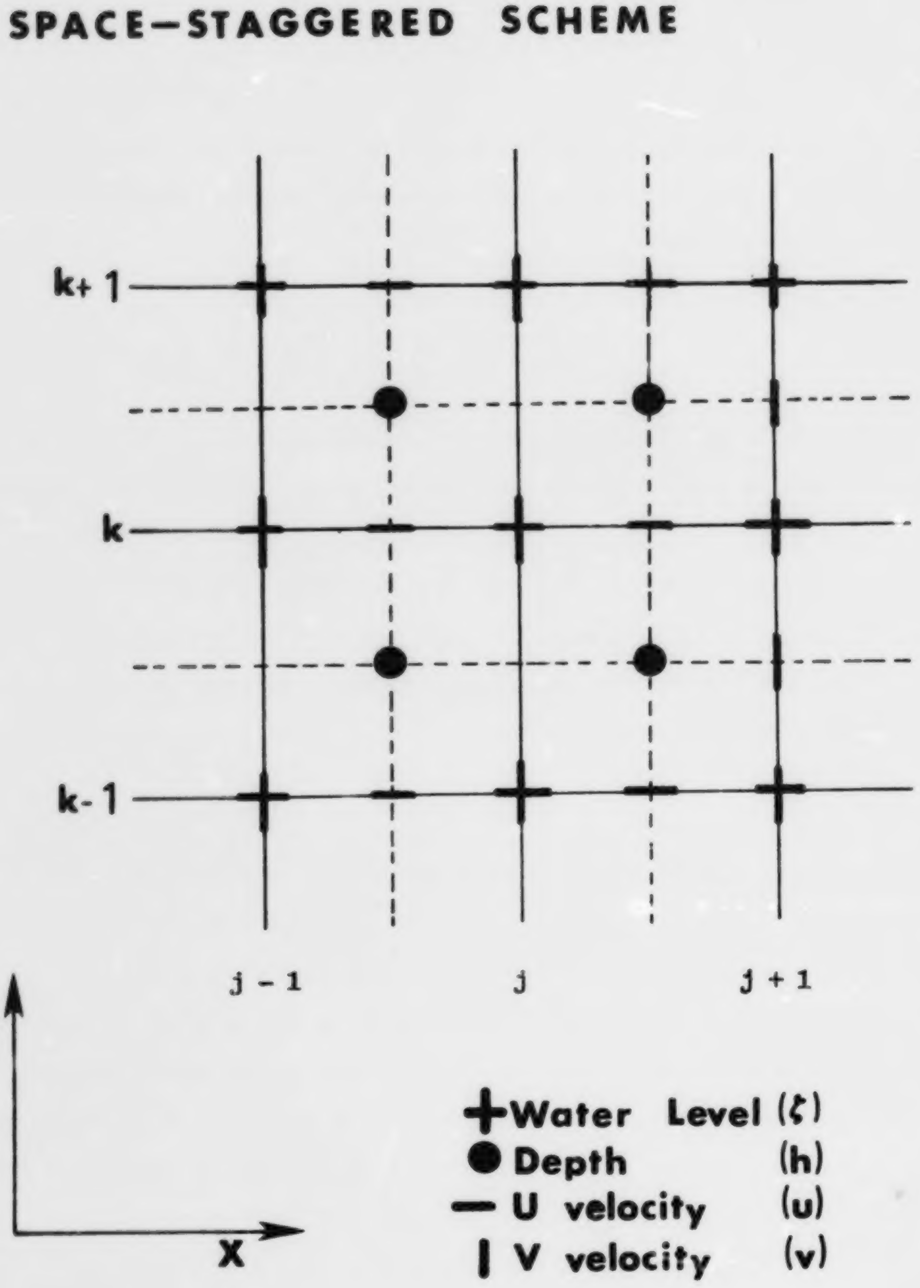

SPACE–STAGGERED SCHEME
k+ 1
k
k- 1
j - 1
j
j + 1
Y
X
+ Water Level (ζ)
● Depth (h)
— U velocity (u)
| V velocity (v)

Figure E-1. The Space Staggered Numerical Scheme

Finite Difference Grid Network

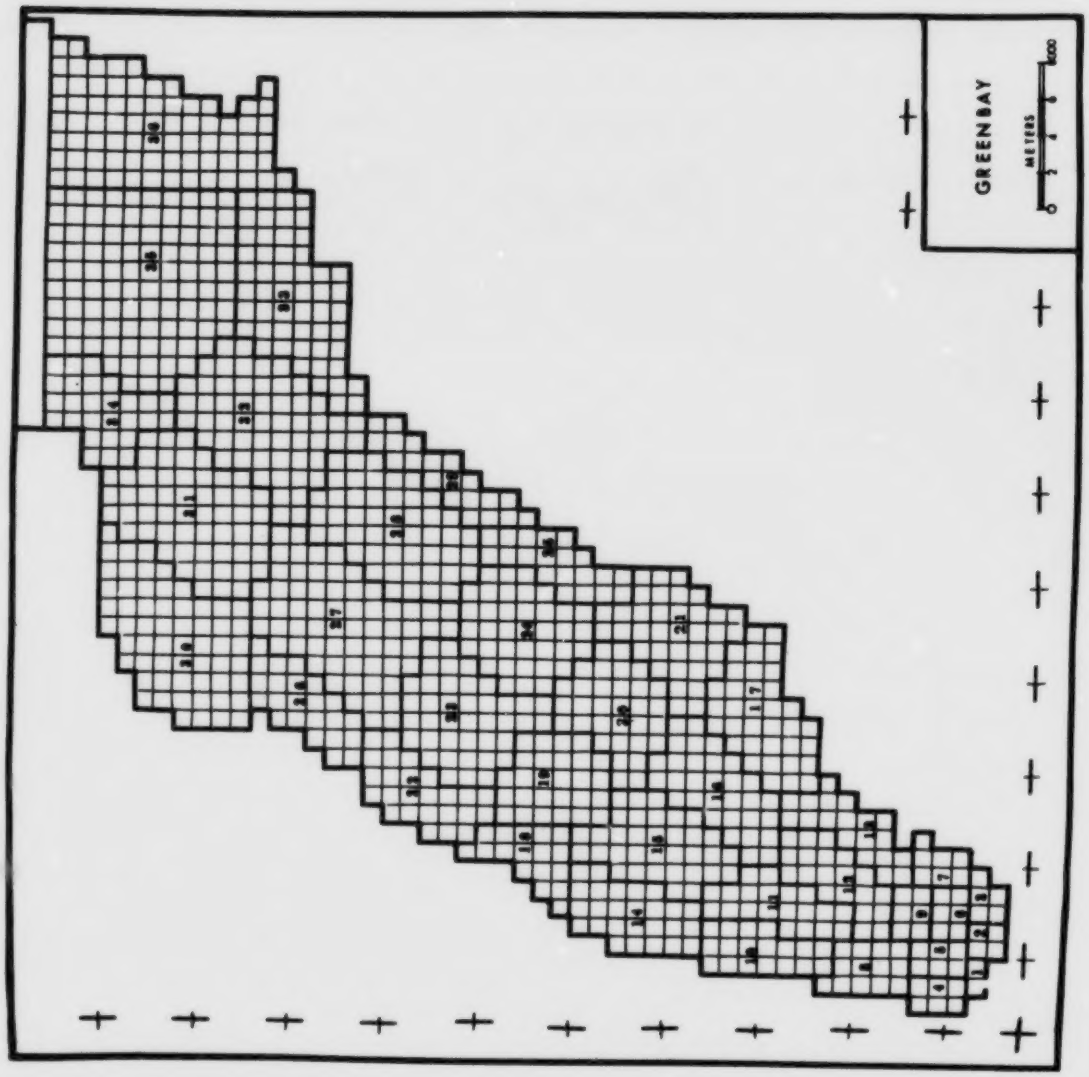
The finite difference grid for the model covers the lower half of Green Bay from the mouth of the Fox River at its southwest corner to the northeast 10km above Sturgeon Bay. There are 55 grids eastward and 53 grids northward. Each grid is 1016m by 1016m. The water depth or the elevation is measured at the center of each grid. Figure E-2 illustrates the grid network used in the computation. The land-water boundary is not a fixed boundary in order to account for the possible flooding of some area near the shore.

Boundary and Boundary Conditions

The boundary of the problem includes a solid boundary at the shore and bottom, an open boundary at the surface, an open boundary at the River mouth and an open boundary at the open Bay. Because the numerical scheme is designed in accordance with the type of boundary conditions, the numerical operations in the two time levels are postulated differently. Therefore, an extensive system is developed for the purpose of tracking the boundary and boundary conditions and matching an appropriate numerical scheme efficiently. The flooding in the shallow flat area around the bay was also considered.

The boundary conditions at the free surface are specified by the atmospheric pressure, wind speed and direction patterns. For the case studies made in the report, seasonal statistical means were sought using the office records of the U.S. Weather Service at Austin Straubel Field in Green Bay for the years 1968 through 1974. In each case, a calm sea state was used as the initial condition. The Chezy roughness coefficients at the bottom of the Bay vary with the depth and the Manning's n. The n values varied from 0.036 for sand and gravel bottoms to 0.075 for shallow weed beds.

Figure E-2. The Finite Difference Grid for the Hydrodynamic Model of Green Bay


GREEN BAY
METERS

The river inflow to Green Bay was calculated by using the data at the Rapide Croche Dam for the corresponding period. Since there is no measured physical data to be used as the boundary condition at the open Bay, a numerical scheme is imposed to insure the mass balance at the boundary. Furthermore, the boundary is located far from the interested region so that the local boundary effect at the open Bay would be minimal.

References

Heaps, N. S.

1969. A two-Dimensional Numerical Sea Model, Phil. Trans. R. Soc. Lond. A265, 93-137.

Lee, K. K.

1974. A Hydrodynamic Model of Green Bay, presented at the Technical Conference on the Water Quality of Lower Green Bay and its Drainage Basin, Green Bay, Wisconsin, November 1974, (Manuscript in preparation).

Leendertse, J. J.

1970. A Water-Quality Simulation Model for Well Mixed Estuaries and Coastal Seas: Volume 1, Principles of Computation, MR-6230-RC, Rand Corporation.

Platzman, G. W.

1959. A Numerical Computation on the Surge of 26 June on Lake Michigan, Geophysics, Vol. 6, No. 3-4, pp. 407-438.

Pritchard, D. W.

1971. Hydrodynamic Models, Estuarine Modeling: An Assessment, Chapter 11, pp. 5-33, Water Pollution Research Series, 16070, DZV 02/71, Environmental Protection Agency.

Wu, Jin

1969. Wind Stress and Surface Roughness at Air-Sea Interface, J. of Geophysical Res., V. 74, No. 2, pp. 444-455.

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APPENDIX F

STORET RETRIEVALS OF THE DATA GENERATED BY THE GREEN BAY STUDY

Statistical Analysis Of All Survey Data At All Stations During The Period Of Study

```
STORET RETRIEVAL DATE 75/06/10                                                                              00000000 00000000000

                              00010       00299       00078       00310       00312       00940       00530
  DATE    TIME DEPTH        WATER         DO        TRANSP        BOD         BOD       CHLORIDE    RESIDUE
  FROM     OF                TEMP        PROBE      SECCHI       5 DAY       6 DAY        CL        TOT NFLT
   TO     DAY   FEET         CENT        MG/L       METERS       MG/L        MG/L        MG/L        MG/L

00/00/00
STATION   NUMBER           928.000     992.000     264.000     148.000     31.0000     173.000     210.000
          MAXIMUM          27.5000     18.6000     7.00000     30.0000     14.0000     40.0000     74.0000
          MINIMUM         .0000000     1.50000     .300000     1.60000     2.90000     2.00000     .100000
          MEAN             13.5958     8.84745     1.35804     5.30128     6.18709     10.6098     10.3952
          VARIANCE         41.5334     7.72969     .441285     9.01541     8.10052     22.1739     138.840
          STAND DEV        6.44464     2.78023     .664293     3.00257     2.84614     4.70892     11.7830
          COEF VAR         .474018     .314241     .489156     .566386     .460013     .443826     1.13351
99/99/99


                              00671       00665       00605       00618       00613       00610       32211       32216
  DATE    TIME DEPTH      PHOS-DIS     PHOS-TOT      ORG N       NO3-N       NO2-N       NH3-N     CHLRPHYL    PHEOPHTN
  FROM     OF               ORTHO                      N          DISS        DISS       TOTAL      A UG/L         A
   TO     DAY   FEET       MG/L P       MG/L P       MG/L        MG/L        MG/L        MG/L      CORRECTD      UG/L

00/00/00
STATION   NUMBER           208.000     210.000     210.000     210.000     210.000     210.000     119.000     109.000
          MAXIMUM         .0639999     .356000     4.10000     1.13000     .137000     3.57000     75.2000     74.0000
          MINIMUM         .0010000    .0020000    .0000000    .0010000    .0000000    .0000000    .0000000    .0000000
          MEAN            .0098363    .0674328     .434280     .150311    .0118712     .174962     16.6513     12.2660
          VARIANCE        .0000739    .0040640     .211451    .0492217    .0002117    .0910575     280.106     296.091
          STAND DEV       .0085947    .0637494     .459838     .221860    .0145170     .301757     16.7364     17.2073
          COEF VAR         .873778     .945376     1.05885     1.47600     1.22268     1.72470     1.00511     1.40284
99/99/99
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Statistical Analysis of All Stations During Each Survey

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STORET RETRIEVAL DATE 75/06/10                                                                     00000000 00000000000

                          00010      00299      00078      00310      00312      00940      00530
 DATE     TIME DEPTH     WATER        DO       TRANSP       BOD        BOD     CHLORIDE   RESIDUE
 FROM      OF             TEMP       PROBE     SECCHI      5 DAY      6 DAY       CL      TOT NFLT
  TO      DAY   FEET      CENT       MG/L      METERS      MG/L       MG/L       MG/L       MG/L

73/09/01
MONTH     NUMBER        104.000    104.000    36.0000    11.0000                           36.0000
          MAXIMUM       20.0000    10.7000    2.10000    11.0000                           60.0000
          MINIMUM       13.0000    3.70000    .300000    3.90000                           1.00000
          MEAN          14.7731    8.65282    1.10361    6.08181                           17.5276
          VARIANCE      1.48536    1.90477    .318581    5.06165                           158.600
          STAND DEV     1.21875    1.38013    .564430    2.24981                           12.5936
          COEF VAR     .0824983    .159501    .511441    .369924                           .718496
73/10/00
74/02/01
MONTH     NUMBER        118.000    185.000               22.0000               22.0000    23.0000
          MAXIMUM       2.00000    18.6000               13.5000               20.0000    61.0000
          MINIMUM      .0000000    1.50000               1.80000               8.00000    .500000
          MEAN          .583048    9.65289               4.58181               13.6636    11.4130
          VARIANCE      .283130    17.5347               9.67491               17.5523    266.786
          STAND DEV     .532100    4.18745               3.11045               4.18954    16.3336
          COEF VAR      .912618    .433802               .678869               .302196    1.43114
74/03/00
74/05/01
MONTH     NUMBER        143.000    143.000    43.0000    15.0000    13.0000    28.0000    28.0000
          MAXIMUM       18.0000    12.5000    7.00000    12.0000    7.00000    18.0000    33.6000
          MINIMUM       4.50000    4.80000    .450000    4.10000    2.90000    3.00000    3.60000
          MEAN          10.2706    11.0964    1.53395    7.91999    4.13846    9.39286    11.0265
          VARIANCE      11.6595    2.46704    1.09014    4.21319    1.07260    9.87708    31.1522
          STAND DEV     3.41460    1.57068    1.04410    2.05240    1.03567    3.14278    5.58142
          COEF VAR      .332462    .141548    .680659    .259167    .250254    .334593    .506086
74/06/00
74/06/01
MONTH     NUMBER        145.000    145.000    46.0000    15.0000    11.0000    31.0000    30.0000
          MAXIMUM       18.0000    11.8000    2.70000    5.30000    14.0000    16.0000    26.0000
          MINIMUM       5.00000    5.20000    .450000    1.60000    8.20000    2.00000    .100000
          MEAN          13.0655    9.86131    1.44565    3.27333    9.52726    9.51613    5.56333
          VARIANCE      7.19884    2.18888    .358436    .876416    2.64226    10.1248    51.8899
          STAND DEV     2.68307    1.47949    .598695    .936171    1.62550    3.18195    7.20347
          COEF VAR      .205355    .150029    .414137    .286000    .170616    .334375    1.29461
74/07/00
```

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STORET RETRIEVAL DATE 75/06/10
                                                                                  00000000 00000C00000

                           00010       00299       00078       00310       00312       00940       00530
  DATE      TIME DEPTH     WATER        DO         TRANSP       BOD         BOD       CHLORIDE    RESIDUE
  FROM       OF            TEMP        PROBE       SECCHI      5 DAY       6 DAY        CL        TOT NFLT
   TO       DAY   FEET     CENT        MG/L        METERS      MG/L        MG/L        MG/L        MG/L

74/07/01
MONTH       NUMBER        136.000     133.000     47.0000     24.0000     7.00000     31.0000     31.0000
            MAXIMUM       27.5000     10.5000     2.40000     30.0000     7.40000     40.0000     20.4000
            MINIMUM       9.00000     1.50000     .300000     2.50000     3.10000     5.00000     .400000
            MEAN          19.3912     7.09917     1.35531     6.79583     4.74265     10.2903     5.14838
            VARIANCE      16.8215     4.47345     .252101     28.7369     1.97292     36.7463     22.1092
            STAND DEV     4.10140     2.11505     .502097     5.36069     1.40460     6.06187     4.70205
            COEF VAR      .211508     .297930     .370466     .788820     .296152     .589085     .913306
74/08/00
74/08/01
MONTH       NUMBER        161.000     161.000     47.0000     31.0000                 31.0000     31.0000
            MAXIMUM       23.0000     10.6000     2.40000     7.40000                 21.0000     36.4000
            MINIMUM       9.00000     2.20000     .450000     3.30000                 3.00000     .100000
            MEAN          18.0329     6.86141     1.34212     4.90322                 10.6452     6.19354
            VARIANCE      11.7553     3.73171     .306312     .976318                 19.0366     71.2052
            STAND DEV     3.42861     1.93176     .553455     .988088                 4.36310     8.43832
            COEF VAR      .190130     .281541     .412373     .201518                 .409867     1.36244
74/09/00
74/09/01
MONTH       NUMBER        121.000     121.000     45.0000     30.0000                 30.0000     31.0000
            MAXIMUM       22.0000     11.4000     2.10000     7.40000                 28.0000     74.0000
            MINIMUM       13.0000     4.10000     .300000     2.50000                 5.00000     1.20000
            MEAN          17.4215     8.48174     1.32355     4.46333                 10.7833     14.9096
            VARIANCE      1.79622     2.69967     .300437     1.64584                 30.5464     261.749
            STAND DEV     1.34023     1.64307     .548121     1.28290                 5.52688     16.1787
            COEF VAR      .0769298    .193718     .414129     .287432                 .512539     1.08512
74/10/00
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STORET RETRIEVAL DATE 75/06/10

                                                                                                     00000000 00000000000



                          00671      00666      00605      00618      00613      00610      32211      32218
 DATE   TIME DEPTH PHOS-DIS   PHOS-TOT    ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
 FROM    OF         ORTHO                  N         DISS       DISS       TOTAL     A UG/L        A
  TO    DAY  FEET   MG/L P     MG/L P     MG/L       MG/L       MG/L       MG/L      CORRECTD    UG/L

73/09/01
MONTH    NUMBER      36.0000    36.0000    36.0000    36.0000    36.0000    36.0000    36.0000    34.0000
         MAXIMUM    .0440000    .356000    1.00000    .113000   .0070000    .574000    70.0000    26.0000
         MINIMUM    .0010000   .0030000   .0000000   .0010000   .0000000   .0000000    3.00000    1.00000
         MEAN       .0075277   .0829162    .336111   .0367499   .0021944    .141472    23.1944    8.02941
         VARIANCE   .0000724   .0084575   .0789443   .0004459   .0000019   .0231131    410.104    48.3931
         STAND DEV  .0085103   .0919645    .280970   .0211152   .0013902    .152030    20.2510    6.95652
         COEF VAR    1.13053    1.10912    .835946    .574566    .633497    1.07463    .873098    .866379
73/10/00
74/02/01
MONTH    NUMBER      23.0000    23.0000    23.0000    23.0000    23.0000    23.0000    3.00000    3.00000
         MAXIMUM    .0320000    .309000    1.60000    .122000   .0350000    .746000    15.9000    2.40000
         MINIMUM    .0010000   .0020000    .100000   .0030000   .0050000   .0210000    9.70000   .0000000
         MEAN       .0090000   .0480848    .273913   .0663910   .0168695    .380043    12.1333    1.33333
         VARIANCE   .0000640   .0042063    .115652   .0017047   .0000868   .0659876    10.9436    1.49333
         STAND DEV  .0080000   .0648546    .340076   .0412862   .0093191    .256881    3.30811    1.22202
         COEF VAR    .888893    1.34872    1.24155    .621894    .552420    .675925    .272647    .916515
74/03/00
74/05/01
MONTH    NUMBER      26.0000    28.0000    28.0000    28.0000    28.0000    28.0000    13.0000    8.00000
         MAXIMUM    .0200000    .210000    .500000    .600000   .0320000    .570000    14.6000    4.50000
         MINIMUM    .0010000   .0130000    .100000   .0200000   .0020000   .0000000    1.50000    1.20000
         MEAN       .0091923   .0629998    .235714    .181428   .0123214    .214000    10.0538    2.85000
         VARIANCE   .0000265   .0021718   .0164551   .0205755   .0000426   .0186969    17.5111    1.77715
         STAND DEV  .0051461   .0466025    .128277    .143442   .0065266    .136737    4.18462    1.33310
         COEF VAR    .559824    .739724    .544208    .790625    .529699    .638958    .416221    .467753
74/06/00
74/06/01
MONTH    NUMBER      30.0000    30.0000    30.0000    30.0000    30.0000    30.0000    17.0000    16.0000
         MAXIMUM    .0300000    .170000    1.40000    .730000   .0570000    .720000    22.8000    8.80000
         MINIMUM    .0020000   .0500000    .100000   .0100000   .0020000   .0100000    5.40000   .0000000
         MEAN       .0090000   .0863329    .533333    .179666   .0144000    .167333    12.2471    3.63124
         VARIANCE   .0000305   .0012378    .167816   .0403754   .0001169   .0339164    33.4876    5.43829
         STAND DEV  .0055211   .0351831    .409653    .200936   .0108138    .184164    5.78685    2.33201
         COEF VAR    .613462    .407528    .768101    1.11839    .750957    1.10058    .472509    .642208
74/07/00
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STORET RETRIEVAL DATE 75/06/10                                                                          00000000 00000000000




                            00671      00665      00605      00618      00613      00610      32211      32218
 DATE     TIME DEPTH PHOS-DIS  PHOS-TOT     ORG N      NO3-N      NO2-N      NH3-N    CHLRPHYL   PHEOPHTN
 FROM      OF          ORTHO                  N        DISS       DISS       TOTAL     A UG/L       A
  TO      DAY   FEET  MG/L P     MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

74/07/01
MONTH     NUMBER      31.0000    31.0000    31.0000    31.0000    31.0000    31.0000    17.0000    15.0000
          MAXIMUM    .0260000    .178000    4.10000    1.13000    .137000    3.57000    57.6000    11.4000
          MINIMUM    .0030000   .0210000    .100000   .0050000   .0010000   .0000000    3.60000    .200000
          MEAN       .0088709   .0616128    .741933    .145064   .0205806    .193226    19.8117    4.72666
          VARIANCE   .0000217   .0011599    .707182   .0642437   .0007655    .408996    188.906    13.1993
          STAND DEV  .0046601   .0340566    .840941    .253464   .0276680    .639528    13.7443    3.63308
          COEF VAR    .525319    .552752    1.13344    1.74725    1.34437    3.30975    .693744    .768635
74/08/00
74/08/01
MONTH     NUMBER      31.0000    31.0000    31.0000    31.0000    31.0000    31.0000    17.0000    17.0000
          MAXIMUM    .0360000    .123000    1.10000    1.08000   .0230000    .330000    75.2000    74.0000
          MINIMUM    .0030000   .0130000    .100000   .0250000   .0010000   .0100000   .0000000    3.10000
          MEAN       .0131290   .0390967    .461290    .246419   .0077097   .0525801    11.0412    33.0411
          VARIANCE   .0000722   .0008752   .0584517    .118661   .0000418   .0092331    434.695    649.360
          STAND DEV  .0084999   .0295841    .241768    .344472   .0064663   .0960891    20.8493    25.4824
          COEF VAR    .647413    .756690    .524112    1.39791    .838728    1.82748    1.88833    .771244
74/09/00
74/09/01
MONTH     NUMBER      31.0000    31.0000    31.0000    31.0000    31.0000    31.0000    16.0000    16.0000
          MAXIMUM    .0639999    .334000    1.90000    .940000   .0809999    1.64000    61.8000    69.3000
          MINIMUM    .0020000   .0140000    .100000   .0200000   .0020000   .0100000   .0000000   .0000000
          MEAN       .0121613   .0836771    .416129    .197096   .0120000    .137967    15.4200    21.6562
          VARIANCE   .0002070   .0080888    .176731   .0662078   .0002091   .0388730    315.081    482.472
          STAND DEV  .0143877   .0899376    .420394    .257309   .0144614    .197162    17.7505    21.9653
        * COEF VAR    1.18307    1.07482    1.01025    1.30550    1.20512    1.42905    1.15114    1.01427
74/10/00
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Listing Of All Data

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STORET RETRIEVAL DATE 75/06/06
                                                                              053002         4290AC053002
                                                                             44 32 10.0 088 00 30.0
                                                                             GREEN BAY STUDY DNR STA 1
                                                                             55      WISCONSIN
                                                                             LAKE MICHIGAN

                                                                             21WIS                 2111202
                                                                             2                    0026 FEET  DEPTH

                            72028      72029      00010      00299      00078      00310      00312      00940      00530
   DATE    TIME DEPTH   AZIMUTH   DISTANCE   WATER        DO       TRANSP       BOD        BOD     CHLORIDE   RESIDUE
   FROM     OF         FR SOUTH   FR SOUTH   TEMP       PROBE      SECCHI      5 DAY      6 DAY       CL      TOT NFLT
    TO     DAY  FEET   DEGREES     FEET      CENT       MG/L       METERS      MG/L       MG/L       MG/L      MG/L

 73/09/17       0003                          18.0        6.0        0.4        11.0                            16
 73/09/17       0007
 73/09/17       0010                          18.0        6.0
 73/09/17       0020                          18.0        6.0
 74/05/22       0003                          15.5        8.8        0.5         9.8                  13         9
 74/05/22       0007
 74/05/22       0013                          15.5        8.8
 74/05/22       0030                          16.0        7.6
 74/06/03       0003                          18.0        7.2        0.6                    9.8       13        20
 74/06/03       0007
 74/06/03       0013                          17.5        7.2
 74/06/03       0030                          16.5        6.2
 74/07/09       0003                          25.0        6.2        0.9        30.0L                 40        20
 74/07/09       0007
 74/07/09       0010                          24.0        4.9
 74/07/09       0016                          22.0        3.3
 74/07/09       0023                          22.0        2.9
 74/07/09       0030                          21.0        2.6
 74/08/12       0003                          23.0        5.7        0.6         4.9                  19        17
 74/08/12       0007                          22.0        4.5
 74/08/12       0010                          22.0        3.6
 74/08/12       0013                          21.0        3.4
 74/08/12       0016                          20.0        3.0
 74/08/12       0020                          19.0        2.9
 74/08/12       0023                          19.0        2.8
 74/08/12       0026                          19.0        2.6
 74/09/04       0003                          22.0        7.2                    5.7                  23        25
 74/09/04       0007
 74/09/04       0020                          20.0        6.5
 74/09/04       0030                          19.0        6.0
                                                                              053002         4290AC053002
                                                                             44 32 10.0 088 00 30.0
                                                                             GREEN BAY STUDY DNR STA 1
                                                                             55      WISCONSIN
                                                                             LAKE MICHIGAN

                                                                             21WIS                 2111202
                                                                             2                    0026 FEET  DEPTH

                         00671      00665      00605      00618      00613      00610      32211      32218
   DATE    TIME DEPTH  PHOS-DIS   PHOS-TOT    ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
   FROM     OF          ORTHO                   N         DISS       DISS      TOTAL     A UG/L        A
    TO     DAY  FEET   MG/L P     MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

 73/09/17       0007    0.049      0.247      1.000       0.03      0.002      0.101      51.00      26.00
 74/05/22       0007    0.017      0.210      0.100       0.18      0.016      0.320      13.30       4.50
 74/06/03       0007    0.012      0.170      0.700       0.28      0.015      0.620      17.10       6.90
 74/07/09       0007    0.026      0.119      4.100       0.07      0.015      3.570      27.00       7.90
 74/08/12       0007    0.019      0.076      0.600       0.07      0.012      0.280      75.20      31.70
 74/09/04       0007    0.009      0.119      0.800       0.12      0.006      0.190      34.20      19.90
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STORET RETRIEVAL DATE 75/06/06
                                                                          053003          4290AC053003
                                                                         44 32 25.0 088 00 14.0
                                                                         GREEN BAY STUDY DNR STA  2
                                                                         55      WISCONSIN
                                                                         LAKE MICHIGAN

                                                                         21WIS                  2111202
                                                                         2                      0026 FEET  DEPTH

                              72028     72029     00010     00299     00078     00310     00312     00940     00530
  DATE    TIME DEPTH  AZIMUTH  DISTANCE   WATER      DO      TRANSP     BOD       BOD     CHLORIDE  RESIDUE
  FROM     OF        FR SOUTH FR SOUTH    TEMP      PROBE    SECCHI    5 DAY     6 DAY      CL     TOT NFLT
   TO     DAY  FEET  DEGREES    FEET      CENT      MG/L     METERS    MG/L      MG/L      MG/L      MG/L

73/09/17       0003                       20.0       3.7       0.4       8.3                             29
73/09/17       0007
73/09/17       0010                       18.0       4.5
73/09/17       0016                       18.0       4.7
74/05/22       0003                       15.0       8.5       0.4       8.0                   9         19
74/05/22       0007
74/05/22       0010                       15.0       8.5
74/05/22       0016                       15.0       8.2
74/06/03       0003                       18.0       6.8       0.6                 9.8        16         22
74/06/03       0007
74/06/03       0010                       17.0       7.4
74/06/03       0020                       16.5       7.8
74/07/09       0003                       24.0       3.4       0.3       7.0                  14          5
74/07/09       0007
74/07/09       0010                       22.0       3.2
74/07/09       0020                       21.0       3.2
74/08/12       0003                       21.5       4.3       0.8       5.3                  20         19
74/08/12       0007                       21.0       3.9
74/08/12       0010                       21.0       3.9
74/09/04       0003                       20.0       4.1       0.3       7.4                  26         79
74/09/04       0007
74/09/04       0010                       19.0       4.7
74/09/04       0023                       19.0       5.2

                                                                          053003          4290AC053003
                                                                         44 32 25.0 088 00 14.0
                                                                         GREEN BAY STUDY DNR STA  2
                                                                         55      WISCONSIN
                                                                         LAKE MICHIGAN

                                                                         21WIS                  2111202
                                                                         2                      0026 FEET  DEPTH

                       00671     00665     00605     00618     00613     00610     32211     32218
  DATE    TIME DEPTH PHOS-DIS  PHOS-TOT    ORG N    NO3-N     NO2-N     NH3-N    CHLRPHYL  PHEOPHTN
  FROM     OF         ORTHO                  N       DISS      DISS     TOTAL    A UG/L       A
   TO     DAY  FEET  MG/L P    MG/L P      MG/L      MG/L      MG/L      MG/L    CORRECTD    UG/L

73/09/17       0007   0.008     0.251     0.900      0.03     0.003     0.524     50.00      8.00
74/05/22       0007   0.017     0.127     0.900      0.18     0.019     0.380     10.10      2.00
74/06/03       0007   0.012     0.170     0.700      0.31     0.019     0.460     17.60      9.10
74/07/09       0007   0.010     0.178     0.900      0.07     0.016     0.660     26.00     11.40
74/08/12       0007   0.012     0.068     1.100      0.08     0.018     0.330     53.50     48.50
74/09/04       0007   0.012     0.328     1.900      0.27     0.014     1.040     47.60     49.30
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STORET RETRIEVAL DATE 75/06/06

053004 4290AC053004
44 33 08.0 087 59 53.0
GREEN BAY OPEN WATER DNR STA 3
55 WISCONSIN
LAKE MICHIGAN

21WIS 2111202
2 0026 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	72028 AZIMUTH FR SOUTH DEGREES	72029 DISTANCE FR SOUTH FEET	00010 WATER TEMP CENT	00299 DO PROBE MG/L	00078 TRANSP SECCHI METERS	00310 BOD 5 DAY MG/L	00312 BOD 6 DAY MG/L	00940 CHLORIDE CL MG/L	00530 RESIDUE TOT NFLT MG/L
73/09/17		0003						7.1			
74/05/22		0003			15.5	8.8	7.0				
74/05/22		0013			14.5	9.0					
74/05/22		0023			11.5	10.0					
74/06/03		0003			17.5	7.0	0.4				
74/06/03		0013			16.5	7.6					
74/06/03		0023			15.0	8.5					
74/07/09		0003			22.0	3.5	0.5				
74/07/09		0010			21.0	3.4					
74/07/09		0016			20.0	3.4					
74/07/09		0023			20.0	3.5					
74/08/12		0003			20.0	4.4	0.8				
74/08/12		0013			20.0	4.4					
74/08/12		0023			19.0	4.6					
74/09/04		0003			19.0	4.5	0.4				
74/09/04		0010			16.0	6.2					
74/09/04		0023			18.0	6.5					

053005 4290AC053005
44 32 55.0 087 58 56.0
GREEN BAY OPEN WATER DNR STA 3A
55 WISCONSIN
LAKE MICHIGAN

21WIS 2111202
2 0026 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	72028 AZIMUTH FR SOUTH DEGREES	72029 DISTANCE FR SOUTH FEET	00010 WATER TEMP CENT	00299 DO PROBE MG/L	00078 TRANSP SECCHI METERS	00310 BOD 5 DAY MG/L	00312 BOD 6 DAY MG/L	00940 CHLORIDE CL MG/L	00530 RESIDUE TOT NFLT MG/L
74/02/19		0003				9.6					

```
STORET RETRIEVAL DATE 75/06/06
                                                                            053006          4290AC053006
                                                                           44 33 53.0 087 59 21.0
                                                                           GREEN BAY OPEN WATER DNR STA 4
                                                                           55      WISCONSIN
                                                                           LAKE MICHIGAN

                                                                           21WIS                    2111202
                                                                           2                       0026 FEET  DEPTH

                             72028      72029      00010       00299       00078     00310      00312     00940     00530
   DATE    TIME DEPTH  AZIMUTH   DISTANCE     WATER        DO        TRANSP      BOD        BOD     CHLORIDE  RESIDUE
   FROM     OF        FR SOUTH  FR SOUTH     TEMP        PROBE       SECCHI     5 DAY      6 DAY       CL     TOT NFLT
    TO     DAY  FEET  DEGREES     FEET       CENT        MG/L        METERS     MG/L       MG/L       MG/L      MG/L

73/09/17        0003                         16.0         6.6         0.3
73/09/17        0007                                                             6.4                                47
73/09/17        0016                         16.0         6.2
73/09/17        0026                         16.0         5.0
74/05/22        0003                         15.0         9.5         0.9
74/05/22        0007                         15.0         9.5                     7.0                  10           34
74/05/22        0013                         13.0         9.2
74/05/22        0023                         11.0        10.2
74/06/03        0003                         17.5         7.2         0.6
74/06/03        0007                                                                       14.0        15           17
74/06/03        0010                         16.0         7.6
74/06/03        0020                         15.0         9.5
74/06/03        0026                         14.0         9.7
74/07/09        0003                         22.0         5.1         0.9
74/07/09        0007                                                             6.5                    9            7
74/07/09        0013                         19.0         4.0
74/07/09        0026                         18.0         3.7
74/08/12        0003                         20.0         6.9         0.8
74/08/12        0007                                                             5.3                   16           24
74/08/12        0016                         20.0         6.2
74/08/12        0033                         18.0         4.6
74/09/04        0003                         20.0         9.1         0.4
74/09/04        0007                                                             4.9                   17           34
74/09/04        0013                         18.0         6.7
74/09/04        0033                         18.0         6.8


                                                                            053006          4290AC053006
                                                                           44 33 53.0 087 59 21.0
                                                                           GREEN BAY OPEN WATER DNR STA 4
                                                                           55      WISCONSIN
                                                                           LAKE MICHIGAN

                                                                           21WIS                    2111202
                                                                           2                       0026 FEET  DEPTH

                        00671      00665      00605       00618      00613      00610      32211      32218
   DATE    TIME DEPTH PHOS-DIS   PHOS-TOT    ORG N       NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
   FROM     OF         ORTHO                   N          DISS       DISS       TOTAL     A UG/L        A
    TO     DAY  FEET  MG/L P     MG/L P      MG/L        MG/L       MG/L       MG/L     CORRECTD     UG/L

73/09/17        0007   0.008      0.234      0.800       0.02      0.002      0.260      49.00      19.00
74/05/22        0007   0.012      0.095      0.500       0.18      0.020      0.260
74/06/03        0007   0.012      0.160      1.100       0.36      0.025      0.720      21.70       1.20
74/07/09        0007   0.006      0.073      0.600       0.11      0.014      0.200      26.60      11.20
74/08/12        0007   0.014      0.058      0.700       0.12      0.015      0.060       5.00      71.00
74/09/04        0007   0.014      0.168      1.200       0.08      0.012      0.530       5.20      69.30
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                  053007          4290AC053007
                                                                 44 34 48.0 087 58 37.0
                                                                 GREEN BAY OPEN WATER UNK STA 5
                                                                 55      WISCONSIN
                                                                 LAKE MICHIGAN

                                                                 21WIS                 2111202
                                                                                      0026 FEET  DEPTH

                            72028     72029      00010      00299      00078     00310     00312     00940     00530
  DATE     TIME DEPTH  AZIMUTH  DISTANCE   WATER       DO       TRANSP     BOD       BOD     CHLORIDE   RESIDUE
  FROM      OF        FR SOUTH  FR SOUTH    TEMP      PROBE     SECCHI    5 DAY     6 DAY      CL      TOT NFLT
   TO      DAY  FEET   DEGREES    FEET      CENT      MG/L      METERS    MG/L      MG/L      MG/L      MG/L

73/09/17        0003                        15.0        8.7       0.5
73/09/17        0007                                                        5.5                                17
73/09/17        0010                        15.0        8.7
74/05/22        0003                        12.0       11.6       1.3
74/05/22        0013                        11.0       11.4
74/05/22        0032                        10.5       11.0
74/06/03        0003                        14.5       10.5       0.9
74/06/03        0010                        14.5       10.3
74/06/03        0016                        14.0       10.4
74/07/09        0003                        21.0        6.7       1.2
74/07/09        0016                        17.0        5.1
74/07/09        0030                        17.0        3.1
74/08/12        0003                        18.5        6.7       1.2
74/08/12        0007                        18.0        5.7
74/08/12        0013                        17.0        4.8
74/08/12        0020                        16.0        2.8
74/08/12        0026                        16.0        2.8
74/09/04        0003                        19.0        8.7       0.8
74/09/04        0010                        17.0        6.7
74/09/04        0020                        17.0        6.0


                                                                  053007          4290AC053007
                                                                 44 34 48.0 087 58 37.0
                                                                 GREEN BAY OPEN WATER UNK STA 5
                                                                 55      WISCONSIN
                                                                 LAKE MICHIGAN

                                                                 21WIS                 2111202
                                                                 2                    0026 FEET  DEPTH

                      00671      00665      00605      00618      00613      00610      32211      32218
  DATE     TIME DEPTH PHOS-DIS   PHOS-TOT    ORG N     NO3-N      NO2-N      NH3-N    CHLRPHYL   PHEOPHTN
  FROM      OF         ORTHO                  N        DISS       DISS       TOTAL    A UG/L        A
   TO      DAY  FEET  MG/L P     MG/L P     MG/L       MG/L       MG/L       MG/L     CORRECTD    UG/L

73/09/17        0007   0.005      0.094      0.600      0.004      0.001      0.072      31.00      12.00
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                       053008          4290AC053008
                                                                       44 34 14.0 087 57 26.0
                                                                       GREEN BAY OPEN WATER DNR STA 5A
                                                                       55       WISCONSIN
                                                                       LAKE MICHIGAN

                                                                       21WIS                2111202
                                                                       2                    0006 FEET  DEPTH

                             72028      72029      00010      00299      00076      00310      00312      00940      00530
  DATE    TIME DEPTH       AZIMUTH    DISTANCE     WATER        DO       TRANSP      BOD        BOD      CHLORIDE   RESIDUE
  FROM     OF             FR SOUTH   FR SOUTH      TEMP       PROBE      SECCHI     5 DAY      6 DAY        CL      TOT NFLT
   TO     DAY  FEET        DEGREES     FEET        CENT        MG/L      METERS      MG/L       MG/L       MG/L       MG/L

74/02/19       0003                                             9.2
74/02/19       0010                                             7.8
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                  053009          4290AC053009
                                                                  44 35 46.0 087 59 46.0
                                                                  GREEN BAY OPEN WATER DNR STA 6
                                                                  55      WISCONSIN
                                                                  LAKE MICHIGAN

                                                                  21WIS               2111202
                                                                  2                  0009 FEET  DEPTH

                         72028      72029      00010      00299      00078     00310     00312     00940     00530
  DATE    TIME DEPTH   AZIMUTH   DISTANCE    WATER        DO       TRANSP     BOD       BOD     CHLORIDE   RESIDUE
  FROM     OF         FR SOUTH   FR SOUTH     TEMP      PROBE      SECCHI    5 DAY     6 DAY       CL      TOT NFLT
   TO     DAY   FEET   DEGREES     FEET       CENT       MG/L      METERS     MG/L      MG/L      MG/L       MG/L

73/09/17        0003                          14.5        9.2        0.6
73/09/17        0007                                                          3.4                            11
74/05/22        0003                          16.0       11.3        0.4
74/05/22        0007                          16.0       11.3                 7.8                   7        14
74/05/22        0010                          11.5        9.4
74/06/03        0003                          15.0       10.0        0.4
74/06/03        0007                                                                    9.4        10        10
74/06/03        0010                          15.0       10.2
74/07/09        0003                          23.0        8.2        0.9
74/07/09        0007                                                          7.8                  13         4
74/07/09        0010                          19.0        5.3
74/08/12        0003                          19.0        7.5        1.0
74/08/12        0007                                                          4.1                  14         3
74/08/12        0013                          19.0        7.7
74/09/04        0003                          19.0       10.2        1.0
74/09/04        0007                                                          6.5                  12        10
74/09/04        0010                          18.0        7.6


                                                                  053009          4290AC053009
                                                                  44 35 46.0 087 59 46.0
                                                                  GREEN BAY OPEN WATER DNR STA 6
                                                                  55      WISCONSIN
                                                                  LAKE MICHIGAN

                                                                  21WIS               2111202
                                                                  2                  0009 FEET  DEPTH

                      00671      00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH PHOS-DIS   PHOS-TOT    ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM     OF          ORTHO                  N         DISS       DISS      TOTAL      A UG/L       A
   TO     DAY   FEET  MG/L P     MG/L P     MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

73/09/17        0007    0.006      0.071     0.700      0.001      0.001      0.025      21.00      12.00
74/05/22        0007    0.009      0.080     0.300       0.03      0.014      0.120      12.50       9.20
74/06/03        0007    0.013      0.100     1.000       0.05      0.012      0.160       8.90
74/07/09        0007    0.005      0.068     0.600       0.01      0.010      0.060      26.00       7.60
74/08/12        0007    0.014      0.028     0.600       0.06      0.007      0.010K      0.00      70.90
74/09/04        0007    0.010      0.076     0.600       0.03      0.003      0.110       6.70      29.20
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                 053010          429UAC053010
                                                                44 35 00.0 087 56 58.0
                                                                GREEN BAY OPEN WATER DNR STA 7
                                                                55      WISCONSIN
                                                                LAKE MICHIGAN

                                                                21W15                   2111202
                                                                2                      0009 FEET  DEPTH

                            72028     72029      00010     00299     00078     00310     00312     00940     00530
  DATE    TIME DEPTH  AZIMUTH  DISTANCE    WATER       DO     TRANSP      BOD       BOD     CHLORIDE  RESIDUE
  FROM     OF         FR SOUTH  FR SOUTH    TEMP     PROBE    SECCHI    5 DAY     6 DAY       CL     TOT NFLT
   TO     DAY  FEET   DEGREES    FEET       CENT      MG/L    METERS     MG/L      MG/L      MG/L      MG/L

73/09/18       0003                          15.0       9.0      0.8
73/09/18       0007                                                        4.0                             28
73/09/18       0010                          15.0       8.0
73/09/18       0030                          15.0       7.7
74/02/19       0003                                     7.3
74/02/19       0007                           1.0       7.0                2.3                 15           3
74/02/19       0016                                     7.0
74/05/22       0003                          13.0      11.7      1.0
74/05/22       0007                          13.0      11.7               12.0                 10          13
74/05/22       0016                          12.0      10.4
74/06/03       0003                          13.5      10.4      1.2
74/06/03       0007                                                                  8.6        9           4
74/06/03       0010                          13.5      10.6
74/06/03       0020                          13.0      10.0
74/07/09       0003                          22.0       8.2      1.2
74/07/09       0007                                                        7.0                 11           2
74/07/09       0013                          21.0       7.5
74/07/09       0020                          16.0       2.7
74/08/12       0003                          19.0       7.9      1.5
74/08/12       0007                                                        4.1                 10         0.4
74/08/12       0010                          19.0       7.6
74/08/12       0020                          18.0       6.2
74/09/04       0003                          20.0       9.8      0.9
74/09/04       0007                                                        4.5                 11           8
74/09/04       0010                          17.0       7.4
74/09/04       0020                          17.0       7.4

                                                                 053010          429UAC053010
                                                                44 35 00.0 087 56 58.0
                                                                GREEN BAY OPEN WATER DNR STA 7
                                                                55      WISCONSIN
                                                                LAKE MICHIGAN

                                                                21W15                   2111202
                                                                2                      0009 FEET  DEPTH

                        00671      00665      00605     00618      00613      00610     32211     32218
  DATE    TIME DEPTH  PHOS-DIS   PHOS-TOT    ORG N    NO3-N      NO2-N      NH3-N    CHLRPHYL  PHEOPHTN
  FROM     OF          ORTHO                   N       DISS       DISS      TOTAL    A UG/L       A
   TO     DAY  FEET   MG/L P     MG/L P      MG/L      MG/L       MG/L       MG/L    CORRECTD    UG/L

73/09/18       0007     0.006      0.101     0.400      0.03      0.002     0.126     27.00     10.00
74/02/19       0007     0.007      0.060     0.100K     0.12      0.021     0.599
74/05/22       0007     0.010      0.073     0.100      0.15      0.011     0.360     12.30      2.40
74/06/03       0007     0.009      0.060     0.800      0.10      0.010     0.110      9.40      3.00
74/07/09       0007     0.007      0.065     0.500      0.01      0.008     0.010K    17.30      0.60
74/08/12       0007     0.018      0.018     0.700      0.04      0.005     0.010K     0.80     12.50
74/09/04       0007     0.010      0.071     0.500      0.02      0.003     0.070      0.00     45.10
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                     053011          4290ACU53011
                                                                    44 36 46.0 087 55 42.0
                                                                    GREEN BAY OPEN WATER DNR STA 8
                                                                    55      WISCONSIN
                                                                    LAKE MICHIGAN

                                                                    21WIS                2111202
                                                                    2                   0026 FEET  DEPTH

                           72028      72029      00010      00299      00078      00310      00312      00940      00530
  DATE    TIME DEPTH   AZIMUTH    DISTANCE    WATER        DO       TRANSP       BOD        BOD      CHLORIDE   RESIDUE
  FROM     OF         FR SOUTH   FR SOUTH     TEMP       PROBE      SECCHI      5 DAY      6 DAY        CL      TOT NFLT
   TO     DAY  FEET    DEGREES     FEET       CENT        MG/L      METERS      MG/L       MG/L        MG/L      MG/L

73/09/18       0003                           15.0        9.2        0.8
73/09/18       0007                                                              4.9                                23
73/09/18       0010                           15.0        8.7
73/09/18       0020                           15.0        8.4
73/09/18       0030                           15.0        8.3
74/02/18       0003                            0.7       15.4
74/02/18       0007                                                              2.5                     16          2
74/02/18       0010                            0.8       10.8
74/02/18       0020                            1.3        8.5
74/05/22       0003                           11.5       11.7        1.8
74/05/22       0013                           10.5       10.8
74/05/22       0030                            9.0       10.8
74/06/03       0003                           12.5       10.5        1.6
74/06/03       0013                           12.5       10.4
74/06/03       0029                           12.0       10.2
74/07/09       0003                           22.0        8.1        1.3
74/07/09       0013                           21.0        6.1
74/07/09       0016                           21.0        7.8
74/07/09       0020                           16.0        3.2
74/08/12       0003                           19.0        8.2        1.8
74/08/12       0010                           19.0        7.9
74/08/12       0020                           18.0        7.7
74/09/04       0003                           18.0        9.0        1.3
74/09/04       0010                           17.0        7.5
74/09/04       0023                           17.0        6.2


                                                                     053011          4290AC053011
                                                                    44 36 46.0 087 55 42.0
                                                                    GREEN BAY OPEN WATER DNR STA 8
                                                                    55      WISCONSIN
                                                                    LAKE MICHIGAN

                                                                    21WIS                2111202
                                                                    2                   0026 FEET  DEPTH

                         00671      00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH   PHOS-DIS   PHOS-TOT    ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM     OF           ORTHO                   N         DISS       DISS       TOTAL     A UG/L        A
   TO     DAY  FEET    MG/L P     MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD      UG/L

73/09/18       0007    0.007      0.094      0.300       0.05      0.003      0.046      21.00       17.00
74/02/18       0007    0.005      0.044      0.100K      0.10      0.022      0.493
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                  053012          4290AC053012
                                                                 44 37 53.0 087 55 02.0
                                                                 GREEN BAY OPEN WATER DNR STA 8A
                                                                 55      WISCONSIN
                                                                 LAKE MICHIGAN

                                                                 21415                  2111202
                                                                 2                      0026 FEET  DEPTH

                        72028    72029     00010    00299     00078     00310    00312    00940     00530
 DATE    TIME DEPTH   AZIMUTH  DISTANCE    WATER      DO      TRANSP     BOD      BOD    CHLORIDE  RESIDUE
 FROM     OF          FR SOUTH FR SOUTH    TEMP     PROBE     SECCHI    5 DAY    6 DAY      CL     TOT NFLT
  TO     DAY  FEET    DEGREES    FEET      CENT     MG/L      METERS    MG/L     MG/L     MG/L      MG/L

74/02/18      0003                          0.8      15.0
74/02/18      0020                          1.5       8.0
74/02/18      0023                          1.2       7.5


                                                                  053013          4290AC053013
                                                                 44 37 30.0 087 53 35.0
                                                                 GREEN BAY OPEN WATER DNR STA 8B
                                                                 55      WISCONSIN
                                                                 LAKE MICHIGAN

                                                                 21415                  2111202
                                                                 2                      0019 FEET  DEPTH

                        72028    72029     00010    00299     00078     00310    00312    00940     00530
 DATE    TIME DEPTH   AZIMUTH  DISTANCE    WATER      DO      TRANSP     BOD      BOD    CHLORIDE  RESIDUE
 FROM     OF          FR SOUTH FR SOUTH    TEMP     PROBE     SECCHI    5 DAY    6 DAY      CL     TOT NFLT
  TO     DAY  FEET    DEGREES    FEET      CENT     MG/L      METERS    MG/L     MG/L     MG/L      MG/L

74/02/18      0003                          1.0       4.8
74/02/18      0007                          1.0       2.8                2.5                  20        0.5
74/02/18      0020                          1.0       3.9


                                                                  053013          4290AC053013
                                                                 44 37 30.0 087 53 35.0
                                                                 GREEN BAY OPEN WATER DNR STA 8B
                                                                 55      WISCONSIN
                                                                 LAKE MICHIGAN

                                                                 21415                  2111202
                                                                 2                      0019 FEET  DEPTH

                       00671     00665     00605    00618     00613     00610    32211     32218
 DATE    TIME DEPTH  PHOS-DIS  PHOS-TOT    ORG N    NO3-N     NO2-N     NH3-N   CHLRPHYL  PHEOPHTN
 FROM     OF          ORTHO                  N       DISS      DISS     TOTAL   A UG/L       A
  TO     DAY  FEET   MG/L P    MG/L P      MG/L     MG/L      MG/L      MG/L   CORRECTD    UG/L

74/02/18      0007    0.028     0.077     0.100K     0.07     0.023     0.746
```

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STORET RETRIEVAL DATE 75/06/06
                                                                  053014          4290AC053014
                                                                 44 37 08.0 087 52 12.0
                                                                 GREEN BAY OPEN WATER DNR STA 8C
                                                                 55      WISCONSIN
                                                                 LAKE MICHIGAN

                                                                 21WIS                    2111202
                                                                 2                        0019 FEET  DEPTH

                          72028     72029      00010      00299      00076      00310      00312      00940     00530
  DATE    TIME DEPTH   AZIMUTH   DISTANCE    WATER       DO       TRANSP      BOD        BOD      CHLORIDE  RESIDUE
  FROM     OF         FR SOUTH   FR SOUTH    TEMP       PROBE     SECCHI     5 DAY      6 DAY       CL      TOT NFLT
   TO     DAY   FEET   DEGREES     FEET      CENT       MG/L      METERS     MG/L       MG/L       MG/L      MG/L

74/02/18        0006                          0.8        4.3
74/02/18        0016                          0.8        3.4
74/06/03        0003                         15.0       10.8       1.0
74/06/03        0007                                                                     9.8        12          7
74/06/03        0010                         15.0       10.4
74/06/03        0016                         14.0        9.2
74/07/09        0003                         24.0        9.6       0.9
74/07/09        0007                         23.5        9.2                  7.4                   12          5
74/07/09        0016                         23.0        8.6
74/08/12        0003                         21.0       10.6       0.6
74/08/12        0007                         21.0       10.6                  7.4                   15         18
74/09/04        0003                         18.0        8.6
74/09/04        0007                         17.0        9.0                  4.9                    8         11



                                                                  053014          4290AC053014
                                                                 44 37 08.0 087 52 12.0
                                                                 GREEN BAY OPEN WATER DNR STA 8C
                                                                 55      WISCONSIN
                                                                 LAKE MICHIGAN

                                                                 21WIS                    2111202
                                                                 2                        0019 FEET  DEPTH

                         00671      00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH   PHOS-DIS   PHOS-TOT     ORG N      NO3-N      NO2-N      NH3-N    CHLRPHYL   PHEOPHTN
  FROM     OF           ORTHO                    N         DISS       DISS       TOTAL     A UG/L        A
   TO     DAY   FEET    MG/L P     MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

74/06/03        0007     0.005      0.100      0.800      0.22      0.019      0.170      18.00       5.50
74/07/09        0007     0.008      0.087      0.500      0.03      0.010      0.240      24.20       3.30
74/08/12        0007     0.015      0.095      0.700      0.04      0.007      0.010K     13.30      58.50
74/09/04        0007     0.010      0.067      0.300      0.09      0.003      0.090       2.50      53.50
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                             053015          429UAC053015
                                                                             44 39 22.0 087 53 49.0
                                                                             GREEN BAY OPEN WATER DNR STA 9
                                                                             55      WISCONSIN
                                                                             LAKE MICHIGAN

                                                                             21A15                   2111202
                                                                             2                      0026 FEET  DEPTH

                            72028     72029     00010     00299     00078     00310     00312     00940     00530
 DATE    TIME DEPTH   AZIMUTH  DISTANCE     WATER        DO    TRANSP       BOD       BOD  CHLORIDE   RESIDUE
 FROM     OF          FR SOUTH  FR SOUTH     TEMP     PROBE    SECCHI     5 DAY     6 DAY        CL   TOT NFLT
  TO     DAY  FEET    DEGREES      FEET     CENT      MG/L    METERS      MG/L      MG/L      MG/L      MG/L

73/09/18      0003                          15.5       9.8       1.0
73/09/18      0007                                                          4.3                             18
73/09/18      0010                          15.0       9.1
73/09/18      0020                          15.0       8.6
74/02/18      0003                           0.6      17.6
74/02/18      0007                           1.0      15.0                  2.1                   9        0.5
74/02/18      0013                           1.0      10.7
74/02/18      0020                           1.3  [illegible].5
74/02/18      0023                           1.0       8.0                  3.1                  17          9
74/02/18      0026                           1.4       8.3
74/05/20      0003                           9.0      11.4       1.2
74/05/20      0010                           9.0      11.3
74/05/20      0020                           6.0      11.8
74/06/03      0003                          12.5      10.4       1.6
74/06/03      0010                          12.5      10.2
74/06/03      0020                          12.0      10.0
74/06/03      0030                          11.0       9.3
74/07/09      0003                          22,0       8.5       1.8
74/07/09      0016                          20.0       5.9
74/07/09      0030                          14.0       5.2
74/08/12      0003                          19.5       8.6       1.8
74/08/12      0013                          19.5       8.3
74/08/12      0023                          19.0       8.1
74/08/12      0026                          15.0       2.8
74/09/04      0003                          19.0       8.4       1.5
74/09/04      0013                          18.0       7.3
74/09/04      0030                          17.0       7.2
                                                                             053015          429UAC053015
                                                                             44 39 22.0 087 53 49.0
                                                                             GREEN BAY OPEN WATER DNR STA 9
                                                                             55      WISCONSIN
                                                                             LAKE MICHIGAN

                                                                             21A15                   2111202
                                                                             2                      0026 FEET  DEPTH

                        00671     00666     00605     00618     00613     00610     32211     32218
 DATE    TIME DEPTH  PHOS-DIS  PHOS-TOT     ORG N    NO3-N     NO2-N     NH3-N  CHLRPHYL  PHEOPHTN
 FROM     OF            ORTHO                   N      DISS      DISS     TOTAL  A UG/L         A
  TO     DAY  FEET    MG/L P    MG/L P      MG/L      MG/L      MG/L      MG/L  CORRECTD      UG/L

73/09/18      0007     0.008     0.058     0.400      0.05     0.003     0.126     51.00     25.00
74/02/18      0007     0.002     0.014     0.200      0.02     0.008     0.089
74/02/18      0023     0.007     0.047     0.100K     0.11     0.026     0.619
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                       053016         4290AC053016
                                                                      44 40 16.0 087 52 39.0
                                                                      GREEN BAY OPEN WATER DNR STA 9A
                                                                      55      WISCONSIN
                                                                      LAKE MICHIGAN

                                                                      21WIS                2111202
                                                                      2                  0026 FEET  DEPTH

                           72028     72029      00010      00299      00078      00310      00312      00940      00530
  DATE    TIME DEPTH  AZIMUTH   DISTANCE    WATER       DO       TRANSP       BOD        BOD      CHLORIDE   RESIDUE
  FROM     OF         FR SOUTH  FR SOUTH    TEMP      PROBE      SECCHI     5 DAY      6 DAY        CL      TOT NFLT
   TO     DAY   FEET   DEGREES    FEET      CENT       MG/L      METERS      MG/L       MG/L       MG/L       MG/L

74/02/18        0003                          1.0       16.4
74/02/18        0020                          1.5        8.8
74/02/18        0026                          1.6        6.3
```

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STORET RETRIEVAL DATE 75/06/06
                                                                  053017          4290AC053017
                                                                 44 39 41.0 087 51 05.0
                                                                 GREEN BAY OPEN WATER DNR STA 9B
                                                                 55      WISCONSIN
                                                                 LAKE MICHIGAN

                                                                 21WIS                  2111202
                                                                 2                      0022 FEET  DEPTH

                           72028     72029     00010     00299     00078     00310     00312     00940     00530
  DATE    TIME DEPTH    AZIMUTH  DISTANCE     WATER       DO      TRANSP      BOD       BOD    CHLORIDE  RESIDUE
  FROM     OF          FR SOUTH  FR SOUTH      TEMP     PROBE     SECCHI     5 DAY     6 DAY      CL     TOT NFLT
   TO     DAY   FEET   DEGREES     FEET        CENT      MG/L     METERS      MG/L      MG/L      MG/L      MG/L

74/02/18         0007                            1.5       5.7                 2.1                  17         4
74/02/18         0020                            0.9       5.1
74/02/18         0026                            1.2       3.3
74/05/20         0003                            8.5      11.8       1.2
74/05/20         0007                            8.5      11.8                           4.5        10         9
74/05/20         0013                            8.5      11.6
74/05/20         0030                            8.0      11.8.
74/06/04         0003                           12.0       9.6       1.6
74/06/04         0007                                                                                8         2
74/06/04         0010                           12.0       9.6
74/06/04         0020                           12.0       9.4
74/06/04         0030                           10.5       7.2
74/07/09         0003                           22.0       8.5       1.6
74/07/09         0007                                                          4.9                   9         1
74/07/09         0013                           21.0       8.0
74/07/09         0030                           12.5       9.3
74/08/13         0003                           20.0       8.1       1.8
74/08/13         0007                                                          4.9                   9      0.1K
74/08/13         0010                           20.0       7.9
74/08/13         0023                           19.5       7.5
74/08/13         0026                           16.0       5.9
74/09/04         0003                           18.0       7.9       1.5
74/09/04         0007                                                          3.3                   6         8
74/09/04         0015                           18.0       7.2
74/09/04         0030                           18.0       5.9
                                                                   053017          4290AC053017
                                                                  44 39 41.0 087 51 05.0
                                                                  GREEN BAY OPEN WATER DNR STA 9B
                                                                  55      WISCONSIN
                                                                  LAKE MICHIGAN

                                                                  21WIS                  2111202
                                                                  2                      0022 FEET  DEPTH

                        00671     00665     00605     00618     00613     00610     32211     32218
  DATE    TIME DEPTH  PHOS-DIS  PHOS-TOT    ORG N    NO3-N     NO2-N     NH3-N   CHLRPHYL  PHEOPHTN
  FROM     OF          ORTHO                  N       DISS      DISS     TOTAL    A UG/L       A
   TO     DAY   FEET  MG/L P    MG/L P      MG/L      MG/L      MG/L      MG/L   CORRECTD     UG/L

74/02/18         0007   0.008     0.046    0.100K     0.10     0.020     0.596
74/05/20         0007   0.009     0.077    0.300      0.06     0.007     0.180     12.60
74/06/04         0007   0.010     0.060    0.200      0.05     0.008     0.060      9.90      9.00
74/07/09         0007   0.008     0.042    0.300      0.03     0.008     0.110     11.30      1.80
74/08/13         0007   0.010     0.014    0.300      0.06     0.005     0.010K     0.00     14.20
74/09/04         0007   0.009     0.033    0.400      0.10     0.063     0.020      3.30     18.90
```

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STORET RETRIEVAL DATE 75/06/06
                                                                      053018          429UAC053018
                                                                     44 38 59.0 087 49 14.0
                                                                     GREEN BAY OPEN WATER DNR STA 9C
                                                                     55      WISCONSIN
                                                                     LAKE MICHIGAN

                                                                     21WIS                  2111202
                                                                     2                     0022 FEET  DEPTH

                             72028      72029       00010       00299      00078      00310      00312     00940     00530
  DATE   TIME DEPTH  AZIMUTH   DISTANCE    WATER        DO        TRANSP       BOD        BOD     CHLORIDE  RESIDUE
  FROM    OF         FR SOUTH  FR SOUTH    TEMP        PROBE      SECCHI      5 DAY      6 DAY       CL     TOT NFLT
   TO    DAY  FEET   DEGREES     FEET      CENT        MG/L       METERS      MG/L       MG/L       MG/L      MG/L

74/02/18        0003                                    15.0
74/02/18        0023                                     4.0





                                                                      053019          429UAC053019
                                                                     44 39 06.0 087 49 58.0
                                                                     GREEN BAY OPEN WATER DNR STA 9CB
                                                                     55      WISCONSIN
                                                                     LAKE MICHIGAN

                                                                     21WIS                  2111202
                                                                     2                     0019 FEET  DEPTH

                             72028      72029       00010       00299      00078      00310      00312     00940     00530
  DATE   TIME DEPTH  AZIMUTH   DISTANCE    WATER        DO        TRANSP       BOD        BOD     CHLORIDE  RESIDUE
  FROM    OF         FR SOUTH  FR SOUTH    TEMP        PROBE      SECCHI      5 DAY      6 DAY       CL     TOT NFLT
   TO    DAY  FEET   DEGREES     FEET      CENT        MG/L       METERS      MG/L       MG/L       MG/L      MG/L

74/02/18        0003                          0.7       14.0
74/02/18        0013                          0.8       10.8
74/02/18        0020                          1.5        2.6
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                        053020          4290AC053020
                                                                        44 32 10.0 087 59 00.0
                                                                        GREEN BAY OPEN WATER DNR STA 10
                                                                        55      WISCONSIN
                                                                        LAKE MICHIGAN

                                                                        21WIS               2111202
                                                                        2                 0006 FEET  DEPTH

                            72028     72029     00010     00299     00078     00310     00312     00940     00530
  DATE    TIME DEPTH      AZIMUTH  DISTANCE     WATER       DO     TRANSP      BOD       BOD    CHLORIDE  RESIDUE
  FROM     OF            FR SOUTH  FR SOUTH      TEMP     PROBE    SECCHI     5 DAY     6 DAY      CL     TOT NFLT
   TO     DAY  FEET      DEGREES     FEET        CENT      MG/L    METERS     MG/L      MG/L      MG/L      MG/L

73/09/17       0003                              17.5       5.2       0.4
73/09/17       0007                                                             7.4                           60
74/02/19       0003                                        10.1
74/02/19       0007                               1.0      10.1                 6.1                 18        59
74/05/22       0003                              15.5       8.8       0.7
74/05/22       0007                              15.0       9.3
74/06/03       0003                              16.5       6.2       0.6
74/06/03       0007                              16.5       6.2
74/07/09       0003                              23.0       4.2       0.8
74/08/12       0003                              22.5       6.9       0.4
74/08/12       0010                              22.5       6.7
74/09/04       0003                              19.0       5.5       0.3
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                                                                        053020          4290AC053020
                                                                        44 32 10.0 087 59 00.0
                                                                        GREEN BAY OPEN WATER DNR STA 10
                                                                        55      WISCONSIN
                                                                        LAKE MICHIGAN

                                                                        21WIS               2111202
                                                                        2                 0006 FEET  DEPTH

                         00671      00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH   PHOS-DIS   PHOS-TOT     ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM     OF           ORTHO                    N         DISS       DISS      TOTAL      A UG/L        A
   TO     DAY  FEET    MG/L P     MG/L P       MG/L       MG/L       MG/L       MG/L      CORRECTD     UG/L

73/09/17       0007     0.009      0.356      0.700       0.03      0.003      0.489      70.00      17.00
74/02/19       0007     0.032      0.309      0.100K      0.11      0.031      0.536      15.90       2.90
```

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STORET RETRIEVAL DATE 75/06/06
                                                                     053021          4290AC053021
                                                                    44 32 03.0 087 57 05.0
                                                                    GREEN BAY OPEN WATER DNR STA 11
                                                                    55       WISCONSIN
                                                                    LAKE MICHIGAN

                                                                    21WIS                 2111202
                                                                    2                    0006 FEET  DEPTH

                             72028     72029     00010     00299     00078     00310     00312     00940     00530
  DATE    TIME DEPTH   AZIMUTH  DISTANCE   WATER       DO     TRANSP      BOD       BOD    CHLORIDE  RESIDUE
  FROM     OF         FR SOUTH  FR SOUTH    TEMP     PROBE    SECCHI     5 DAY     6 DAY       CL     TOT NFLT
   TO     DAY  FEET    DEGREES    FEET      CENT     MG/L     METERS     MG/L      MG/L      MG/L      MG/L

73/09/17       0003                         17.0       4.2       0.4
73/09/17       0007                                                        4.6                            32
74/02/19       0003                                    9.8
74/02/19       0007                                    8.9
74/05/22       0003                         15.5      11.1       0.9
74/05/22       0010                         15.0      10.8
74/06/03       0003                         16.5       7.4       0.8
74/06/03       0010                         16.5       7.5
74/07/09       0003                         24.0       8.2       0.9
74/07/09       0010                         22.5       3.2
74/08/12       0003                         22.0       7.8       0.6
74/08/12       0010                         22.0       7.8
74/09/04       0003                         19.0       8.4       0.3
74/09/04       0007                         18.0       6.9


                                                                     053021          4290AC053021
                                                                    44 32 03.0 087 57 05.0
                                                                    GREEN BAY OPEN WATER DNR STA 11
                                                                    55       WISCONSIN
                                                                    LAKE MICHIGAN

                                                                    21WIS                 2111202
                                                                    2                    0006 FEET  DEPTH

                        00671     00665     00605     00618     00613     00610     32211     32218
  DATE    TIME DEPTH  PHOS-DIS  PHOS-TOT    ORG N    NO3-N     NO2-N     NH3-N   CHLRPHYL  PHEOPHTN
  FROM     OF           ORTHO                 N       DISS      DISS     TOTAL   A UG/L       A
   TO     DAY  FEET   MG/L P    MG/L P     MG/L      MG/L      MG/L      MG/L   CORRECTD    UG/L

73/09/17       0007    0.023     0.251     0.400      0.04     0.004     0.325     61.00     11.00
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STORET RETRIEVAL DATE 75/06/06
                                                                   053022          4290AC053022
                                                                   44 32 27.0 087 56 02.0
                                                                   GREEN BAY OPEN WATER DNR STA 12
                                                                   55      WISCONSIN
                                                                   LAKE MICHIGAN

                                                                   21WIS              2111202
                                                                   2                  0009 FEET  DEPTH

                        72028      72029      00010      00299      0007B      00310      00312      00940      00530
  DATE    TIME DEPTH  AZIMUTH   DISTANCE     WATER       DO        TRANSP      BOD        BOD      CHLORIDE   RESIDUE
  FROM     OF         FR SOUTH  FR SOUTH     TEMP       PROBE      SECCHI     5 DAY      6 DAY        CL      TOT NFLT
   TO     DAY  FEET   DEGREES     FEET       CENT       MG/L       METERS      MG/L       MG/L       MG/L       MG/L

73/09/17       0003                          16.0        7.1        0.4
73/09/17       0007                                                                                               24
74/02/19       0003                           0.7       12.8
74/02/19       0007                           1.3        6.2                   9.3                     18         30
74/05/22       0003                          15.5       11.1        0.9
74/05/22       0007                          15.5       11.1                   8.6                     13         15
74/05/22       0010                          14.5       10.0
74/06/03       0003                          17.0       10.0
74/06/03       0007                                                                       9.8          14          7
74/06/03       0010                          17.0        9.8
74/07/09       0003                          24.5        9.7        0.8
74/07/09       0007                                                            8.1                     15          7
74/07/09       0010                          23.0        9.3
74/08/12       0003                          22.0        8.2        0.9
74/08/12       0007                                                            6.5                     17         17
74/08/12       0010                          22.0        8.2
74/09/04       0003                          19.0       10.0        0.6
74/09/04       0007                                                            5.7                     21         21
74/09/04       0010                          18.0        7.0
                                                                    053022          4290AC053022
                                                                    44 32 27.0 087 56 02.0
                                                                    GREEN BAY OPEN WATER DNR STA 12
                                                                    55      WISCONSIN
                                                                    LAKE MICHIGAN

                                                                    21WIS              2111202
                                                                    2                  0009 FEET  DEPTH

                         00671      00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH  PHOS-DIS   PHOS-TOT     ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM     OF           ORTHO                   N         DISS       DISS      TOTAL     A UG/L        A
   TO     DAY  FEET    MG/L P     MG/L P      MG/L       MG/L       MG/L        MG/L     CORRECTD     UG/L

73/09/17       0007    0.006      0.199      0.100       0.03      0.004      0.473      51.00      15.00
74/02/19       0007    0.007      0.117      0.100K      0.02      0.033      0.578
74/05/22       0007    0.016      0.117      0.200       0.29      0.017      0.570      14.60       1.20
74/06/03       0007    0.004      0.120      1.200       0.59      0.027      0.310      22.80       5.40
74/07/09       0007    0.007      0.089      0.800       0.04      0.010      0.100      25.90       6.80
74/08/12       0007    0.022      0.074      0.600       0.11      0.016      0.200      10.10      58.50
74/09/04       0007    0.064      0.241      1.000       0.12      0.009      0.240       3.42      12.50
```

STORET RETRIEVAL DATE 75/06/06

053023 429UAC053023
44 33 04.0 087 57 08.0
GREEN BAY OPEN WATER UNK STA 13
55 WISCONSIN
LAKE MICHIGAN

21WIS 2111202
2 0009 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	72028 AZIMUTH FR SOUTH DEGREES	72029 DISTANCE FR SOUTH FEET	00010 WATER TEMP CENT	00299 DO PROBE MG/L	00078 TRANSP SECCHI METERS	00310 BOD 5 DAY MG/L	00312 BOD 6 DAY MG/L	00940 CHLORIDE CL MG/L	00530 RESIDUE TOT NFLT MG/L
73/09/17		0003			16.0	5.7	0.4				
73/09/17		0007									39
74/02/19		0003				9.2					
74/02/19		0007			1.0	9.0		5.5		16	20
74/02/19		0010				8.3					
74/05/22		0003			15.5	10.0	0.9				
74/05/22		0007			15.5	11.1		6.5		12	19
74/05/22		0010			13.5	8.8					
74/06/03		0003			16.0	7.6	0.9				
74/06/03		0007							8.2	19	12
74/06/03		0010			16.0	7.8					
74/07/09		0003			24.0	8.5	0.9				
74/07/09		0007						7.0		19	9
74/07/09		0010			24.0	8.4					
74/08/12		0003			22.0	7.6	0.4				
74/08/12		0007						6.5		21	36
74/08/12		0010			22.0	7.6					
74/09/04		0003			18.0	8.1	0.4				
74/09/04		0007						5.7		21	22
74/09/04		0010			18.0	7.3					

053023 429UAC053023
44 33 04.0 087 57 08.0
GREEN BAY OPEN WATER UNK STA 13
55 WISCONSIN
LAKE MICHIGAN

21WIS 2111202
2 0009 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	00605 ORG N N MG/L	00618 NO3-N DISS MG/L	00613 NO2-N DISS MG/L	00610 NH3-N TOTAL MG/L	32211 CHLRPHYL A UG/L CORRECTD	32218 PHEOPHTN A UG/L
73/09/17		0007	0.022	0.200	0.000	0.04	0.004	0.579	61.00	11.00
74/02/19		0007	0.010	0.048	0.100K	0.11	0.035	0.525		
74/05/22		0007	0.018	0.108	0.200	0.20	0.013	0.300	9.50	1.20
74/06/03		0007	0.009	0.110	1.100	0.73	0.025	0.450	18.20	5.20
74/07/09		0007	0.003	0.130	0.700	0.04	0.015	0.100	35.30	5.10
74/08/12		0007	0.034	0.123	0.800	0.11	0.014	0.310	1.60	74.00
74/09/04		0007	0.048	0.218	0.600	0.11	0.011	0.190	61.80	0.00

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STORET RETRIEVAL DATE 75/06/06
                                                                    053024          4290AC053024
                                                                   44 33 26.0 087 55 37.0
                                                                   GREEN BAY OPEN WATER DNR STA 13A
                                                                   55       WISCONSIN
                                                                   LAKE MICHIGAN

                                                                   21WIS                  2111202
                                                                   2                    0009 FEET  DEPTH

                            72028     72029     00010     00299     00078     00310     00312     00940     00530
  DATE    TIME DEPTH  AZIMUTH   DISTANCE    WATER       DO      TRANSP      BOD       BOD     CHLORIDE  RESIDUE
  FROM     OF         FR SOUTH  FR SOUTH    TEMP      PROBE     SECCHI     5 DAY     6 DAY       CL     TOT NFLT
   TO     DAY  FEET   DEGREES     FEET      CENT       MG/L     METERS     MG/L      MG/L       MG/L      MG/L

74/02/19       0003                                     9.5
74/02/19       0007                          1.0        9.5                 3.4                  14        11
74/02/19       0010                                     6.8
74/05/22       0003                         15.5       11.6       0.9
74/05/22       0010                         15.0       11.0
74/06/03       0003                         16.5        9.9       0.8
74/06/03       0010                         16.5       10.0
74/07/09       0003                         24.0        9.2       0.9
74/07/09       0010                         24.0        9.4
74/08/12       0003                         22.0        8.1       0.8
74/08/12       0010                         22.0        7.2
74/09/04       0003                         19.0        9.9       0.6
74/09/04       0010                         18.0        6.1

                                                                    053024          4290AC053024
                                                                   44 33 26.0 087 55 37.0
                                                                   GREEN BAY OPEN WATER DNR STA 13A
                                                                   55       WISCONSIN
                                                                   LAKE MICHIGAN

                                                                   21WIS                  2111202
                                                                   2                    0009 FEET  DEPTH

                           00671     00665     00605      00618     00613     00610     32211     32218
  DATE    TIME DEPTH  PHOS-DIS  PHOS-TOT     ORG N      NO3-N     NO2-N     NH3-N    CHLRPHYL  PHEOPHTN
  FROM     OF           ORTHO                   N        DISS      DISS     TOTAL     A UG/L       A
   TO     DAY  FEET    MG/L P    MG/L P      MG/L       MG/L      MG/L      MG/L    CORRECTD     UG/L

74/02/19       0007     0.001     0.051     0.100K      0.12     0.030     0.688
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STORET RETRIEVAL DATE 75/06/06
                                                                         053025          4290AC053025
                                                                         44 39 16.0 087 55 05.0
                                                                         GREEN BAY OPEN WATER DNR STA 14
                                                                         55      WISCONSIN
                                                                         LAKE MICHIGAN

                                                                         21WIS                  2111202
                                                                         2                      0009 FEET  DEPTH

                           72028      72029      00010      00299      00078      00310      00312      00940     00530
  DATE    TIME DEPTH    AZIMUTH   DISTANCE     WATER        DO       TRANSP       BOD        BOD      CHLORIDE   RESIDUE
  FROM     OF          FR SOUTH   FR SOUTH      TEMP      PROBE      SECCHI      5 DAY      6 DAY        CL      TOT NFLT
   TO     DAY  FEET    DEGREES      FEET        CENT       MG/L      METERS      MG/L       MG/L        MG/L       MG/L

73/09/18       0003                             15.5        8.4        0.5
73/09/18       0007                                                                                                 27
73/09/18       0010                             15.5        8.3
73/09/18       0013                             15.0        8.0
74/02/19       0003                                         8.9
74/02/19       0007                                         6.3
74/05/22       0003                             15.0       11.2        0.9
74/05/22       0007                             15.0       11.4                   11.0                    15        14
74/05/22       0010                             13.5        8.6
74/06/03       0003                             15.5        9.5        0.9
74/06/03       0007                             15.0        9.6                               8.2         14        10
74/07/09       0003                             25.0       10.1        0.6
74/07/09       0007                                                                9.4                    14         4
74/07/09       0013                             24.0        9.8
74/08/12       0003                             21.5        8.4        0.8
74/08/12       0007                                                                6.5                    16         8
74/08/12       0010                             21.0        8.4
74/09/04       0003                             18.0        9.6        0.6
74/09/04       0007                                                                6.5                    13        12
74/09/04       0010                             18.0        7.2
```

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                                                                          053025          4290AC053025
                                                                          44 39 16.0 087 55 05.0
                                                                          GREEN BAY OPEN WATER DNR STA 14
                                                                          55      WISCONSIN
                                                                          LAKE MICHIGAN

                                                                          21WIS                  2111202
                                                                          2                      0009 FEET  DEPTH

                        00671      00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH  PHOS-DIS   PHOS-TOT    ORG N     NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM     OF          ORTHO                   N        DISS       DISS       TOTAL     A UG/L       A
   TO     DAY  FEET    MG/L P     MG/L P      MG/L      MG/L       MG/L       MG/L     CORRECTD     UG/L

73/09/18       0007     0.027      0.182      0.100      0.09      0.007      0.266      39.00      12.00
74/05/22       0007     0.009      0.125      0.200      0.39      0.013      0.390      13.00       4.00
74/06/03       0007     0.008      0.130      1.400      0.42      0.015      0.380      13.40       8.80
74/07/09       0007     0.006      0.103      0.600      0.02      0.005      0.140      57.60       5.60
74/08/12       0007     0.036      0.103      0.600      0.11      0.023      0.180       9.20      27.00
74/09/04       0007     0.015      0.125      0.300      0.08      0.003      0.050      20.10      25.10
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                 053027          4290AC053027
                                                                 44 35 44.0 087 54 16.0
                                                                 GREEN BAY OPEN WATER GNR STA 15
                                                                 55      WISCONSIN
                                                                 LAKE MICHIGAN

                                                                 21WIS                2111202
                                                                 2                   0013 FEET  DEPTH

                             72028      72029      00010      00299      00078      00310      00312      00940      00530
  DATE    TIME DEPTH    AZIMUTH    DISTANCE   WATER       DO       TRANSP      BOD        BOD      CHLORIDE   RESIDUE
  FROM     OF          FR SOUTH   FR SOUTH    TEMP       PROBE     SECCHI     5 DAY      6 DAY        CL      TOT NFLT
   TO     DAY   FEET   DEGREES      FEET      CENT       MG/L      METERS      MG/L       MG/L       MG/L       MG/L

73/09/18        0003                          15.0        9.6        0.8
73/09/18        0007                                                                                                12
73/09/18        0010                          15.0        9.5
73/09/18        0013                          15.0        9.1
74/02/19        0006                                      5.2
74/02/19        0015                                      5.7
74/05/22        0003                          15.5       11.4        0.8
74/05/22        0016                          14.0       10.2
74/06/03        0003                          15.0       10.8        0.9
74/06/03        0010                          15.0       10.8
74/07/09        0003                          23.0        9.1        0.8
74/07/09        0007                          23.0        8.5
74/08/12        0003                          21.0        8.7        0.6
74/08/12        0013                          21.0        8.7
74/09/04        0003                          18.0        8.7        0.9
74/09/04        0010                          17.0        8.6


                                                                 053027          4290AC053027
                                                                 44 35 44.0 087 54 16.0
                                                                 GREEN BAY OPEN WATER GNR STA. 15
                                                                 55      WISCONSIN
                                                                 LAKE MICHIGAN

                                                                 21WIS                2111202
                                                                 2                   0013 FEET  DEPTH

                            00671      00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH   PHOS-DIS   PHOS-TOT    ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM     OF            ORTHO                  N         DISS       DISS      TOTAL     A UG/L        A
   TO     DAY   FEET    MG/L P     MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

73/09/18        0007     0.008      0.058      0.500       0.07      0.003      0.126      19.00       8.00
```

```
STORET RETRIEVAL DATE 75/06/06
                                                         053028          4290AC053028
                                                         44 37 34.0 087 51 02.0
                                                         GREEN BAY OPEN WATER DNR STA 16
                                                         55      WISCONSIN
                                                         LAKE MICHIGAN

                                                         21WIS                2111202
                                                         2                  0013 FEET  DEPTH

                         72028     72029     00010     00299     00078     00310     00312     00940     00530
  DATE    TIME DEPTH   AZIMUTH  DISTANCE     WATER        DO    TRANSP       BOD       BOD  CHLORIDE   RESIDUE
  FROM     OF         FR SOUTH  FR SOUTH      TEMP     PROBE    SECCHI     5 DAY     6 DAY        CL  TOT NFLT
   TO     DAY  FEET    DEGREES      FEET      CENT      MG/L    METERS      MG/L      MG/L      MG/L      MG/L

73/09/18        0003                          15.5       8.7       0.9
73/09/18        0007                                                                                        20
73/09/18        0010                          15.5       8.5
73/09/18        0020                          15.0       8.1
74/02/18        0003                           0.6       5.2
74/02/18        0007                                     5.2                 2.1                  18         9
74/02/18        0013                           0.8       3.7
74/05/20        0003                           9.0      11.2       0.9
74/05/20        0007                                                                   4.9        18        10
74/05/20        0013                           9.0      11.2
74/05/20        0023                           9.0      11.3
74/06/03        0003                          14.5      10.8       1.0
74/06/03        0010                          14.5      10.5
74/06/03        0020                          13.0       9.0
74/07/09        0003                          23.0       8.5       2.4
74/07/09        0010                          22.0       7.9
74/07/09        0023                          22.0       7.6
74/08/13        0003                          20.0       8.0       1.6
74/08/13        0010                          20.0       7.9
74/08/13        0023                          17.0       7.8
74/09/04        0003                          18.0       8.2       1.3
74/09/04        0023                          17.0       8.0

                                                         053028          4290AC053028
                                                         44 37 34.0 087 51 02.0
                                                         GREEN BAY OPEN WATER DNR STA 16
                                                         55      WISCONSIN
                                                         LAKE MICHIGAN

                                                       . 21WIS                2111202
                                                         2                  0013 FEET  DEPTH

                         00671     00666     00605     00618     00613     00610     32211     32218
  DATE    TIME DEPTH  PHOS-DIS  PHOS-TOT     ORG N     NO3-N     NO2-N     NH3-N  CHLRPHYL  PHEOPHTN
  FROM     OF            ORTHO                   N      DISS      DISS     TOTAL    A UG/L         A
   TO     DAY  FEET     MG/L P    MG/L P      MG/L      MG/L      MG/L      MG/L  CORRECTD      UG/L

73/09/18        0007     0.005     0.063     0.500      0.11     0.001     0.038     50.00     15.00
74/02/18        0007     0.020     0.045    0.100K      0.10     0.014     0.472
74/05/20        0007     0.006     0.086     0.500      0.14     0.012     0.190     13.10
```

STORET RETRIEVAL DATE 75/06/06

US3029 4290ACUS3029
44 39 11.0 087 47 12.0
GREEN BAY OPEN WATER DNR STA 16A
55 WISCONSIN
LAKE MICHIGAN

21615 2111202
2 0019 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	72028 AZIMUTH FR SOUTH DEGREES	72029 DISTANCE FR SOUTH FEET	00010 WATER TEMP CENT	00299 DO PROBE MG/L	00078 TRANSP SECCHI METERS	00310 BOD 5 DAY MG/L	00312 BOD 6 DAY MG/L	00940 CHLORIDE CL MG/L	00530 RESIDUE TOT NFLT MG/L
73/09/18		0003			15.5	9.0	1.2				15
73/09/18		0007									
73/09/18		0010			15.5	9.0					
73/09/18		0020			15.5	9.0					
74/02/20		0000			0.0	9.2					
74/02/20		0002			0.0	12.4					
74/02/20		0005			0.0	11.8					
74/02/20		0006	315.0	4000.0	0.2	12.6		5.3		9	0.5
74/02/20		0007									
74/02/20		0010			0.0	8.2					
74/02/20		0013	315.0	4000.0	0.2	5.4					
74/02/20		0015			0.1	2.5		7.0		18	21
74/02/20		0020			0.1	2.5					
74/02/20		0023	315.0	4000.0	1.0	1.8					
74/02/20		0026			1.0	1.7					
74/05/20		0003			9.0	12.4	1.2				
74/05/20		0010			9.0	12.0					
74/05/20		0020			9.0	12.0					
74/06/04		0003			14.0	9.5	1.5				
74/06/04		0013			14.0	9.4					
74/06/04		0023			14.0	9.4					
74/07/09		0003			24.0	9.2	1.0				
74/07/09		0010			23.0	8.9					
74/07/09		0020			24.0	8.8					
74/08/13		0003			20.0	8.4	1.5				
74/08/13		0010			19.5	8.3					
74/08/13		0020			19.5	8.3					
74/09/05		0003			18.0	9.6	1.6				
74/09/05		0010			18.0	9.6					
74/09/05		0023			18.0	9.5					

US3029 4290ACUS3029
44 39 11.0 087 47 12.0
GREEN BAY OPEN WATER DNR STA 16A
55 WISCONSIN
LAKE MICHIGAN

21615 2111202
2 0019 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	00605 ORG N N MG/L	00618 NO3-N DISS MG/L	00613 NO2-N DISS MG/L	00610 NH3-N TOTAL MG/L	32211 CHLRPHYL A UG/L CORRECTD	32218 PHEOPHTN A UG/L
73/09/18		0007	0.005	0.046	0.000	0.02	0.002	0.095	7.00	5.00
74/02/20		0007	0.005	0.005	1.600	0.04	0.005	0.058	9.70	0.00
74/02/20		0020	0.019	0.053	0.800	0.10	0.010	0.609		

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STORET RETRIEVAL DATE 75/06/06
                                                                          053030          4290AC053030
                                                                          44 39 58.0 087 48 56.0
                                                                          GREEN BAY OPEN WATER DNR STA 168
                                                                          55      WISCONSIN
                                                                          LAKE MICHIGAN

                                                                          21WIS                  2111202
                                                                          2                     0026 FEET  DEPTH

                             72028      72029      00010      00299      00078      00310      00312      00940      00530
  DATE    TIME DEPTH  AZIMUTH   DISTANCE    WATER        DO      TRANSP       BOD        BOD     CHLORIDE  RESIDUE
  FROM     OF        FR SOUTH   FR SOUTH     TEMP      PROBE     SECCHI     5 DAY      6 DAY        CL     TOT NFLT
   TO     DAY  FEET   DEGREES     FEET       CENT       MG/L     METERS      MG/L       MG/L       MG/L       MG/L

74/02/20        0003     315.0     4000.0        0.0       10.0
74/02/20        0005                             0.0       11.0
74/02/20        0006                             0.0        9.3
74/02/20        0010     315.0     4000.0        0.0        5.9
74/02/20        0012                             0.0        7.4
74/02/20        0019                             0.0        3.0
74/02/20        0020     315.0     4000.0        0.1        4.6
74/02/20        0026     315.0     4000.0        1.2        1.7
74/02/20        0027                             1.0        1.5
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                  153001         4290AC153001
                                                                 44 40 54.0 087 51 56.0
                                                                 GREEN BAY OPEN WATER DNR STA 16C
                                                                 55      WISCONSIN
                                                                 LAKE MICHIGAN

                                                                 21615                 2111202
                                                                 2                    0022 FEET  DEPTH

                           72028      72029      00010      00299      00078      00310      00312      00940     00530
  DATE    TIME DEPTH    AZIMUTH   DISTANCE     WATER        DO      TRANSP       BOD        BOD     CHLORIDE  RESIDUE
  FROM     OF          FR SOUTH   FR SOUTH     TEMP       PROBE     SECCHI     5 DAY      6 DAY        CL     TOT NFLT
   TO     DAY   FEET    DEGREES     FEET       CENT        MG/L     METERS      MG/L       MG/L       MG/L      MG/L

74/02/20        0002    315.0     5000.0        0.0       11.5
74/02/20        0003                            0.0        9.2
74/02/20        0004    315.0     2500.0        0.0        9.5
74/02/20        0005    315.0    10000.0        0.0       12.2
74/02/20        0006    315.0     5000.0        0.0        8.8
74/02/20        0007                            0.0        6.8                  9.0                   13          3
74/02/20        0010    315.0     5000.0        0.0        5.6
74/02/20        0011    315.0    10000.0        0.0        9.3
74/02/20        0012                            0.0        5.7
74/02/20        0013    315.0     2500.0        0.1        6.6
74/02/20        0019    315.0    10000.0        0.1        5.8
74/02/20        0020                            0.0        3.8
74/02/20        0021    315.0     5000.0        0.0        4.5
74/02/20        0026                            1.0        1.7                 13.5                   19         61
74/02/20        0028    315.0     2500.0        1.0        2.6
74/02/20        0029    315.0     5000.0        1.0        2.6
74/02/20        0030    315.0    10000.0        1.0        3.4


                                                                  153001         4290AC153001
                                                                 44 40 54.0 087 51 56.0
                                                                 GREEN BAY OPEN WATER DNR STA 16C
                                                                 55      WISCONSIN
                                                                 LAKE MICHIGAN

                                                                 21615                 2111202
                                                                 2                    0022 FEET  DEPTH

                          00671      00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH   PHOS-DIS   PHOS-TOT     ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM     OF            ORTHO                   N         DISS       DISS      TOTAL      A UG/L       A
   TO     DAY   FEET    MG/L P     MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

74/02/20        0007    0.003      0.011      0.300       0.09      0.013      0.247
74/02/20        0026    0.012      0.096      0.300       0.09      0.019      0.719
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STORET RETRIEVAL DATE 75/06/06
                                                                        053031          4290AC053031
                                                                       44 36 43.0 087 58 21.0
                                                                       GREEN BAY OPEN WATER UNK STA 17
                                                                       55      WISCONSIN
                                                                       LAKE MICHIGAN

                                                                       21WIS                2111202
                                                                       2                    0009 FEET  DEPTH

                                72028     72029      00010      00299      00078      00310      00312      00940      00530
  DATE    TIME DEPTH   AZIMUTH   DISTANCE   WATER       DO       TRANSP      BOD        BOD      CHLORIDE   RESIDUE
  FROM     OF          FR SOUTH  FR SOUTH   TEMP      PROBE      SECCHI     5 DAY      6 DAY       CL       TOT NFLT
   TO     DAY  FEET    DEGREES     FEET     CENT       MG/L      METERS      MG/L       MG/L       MG/L       MG/L

73/09/18       0003                         14.5       10.2        1.0
73/09/18       0007                                                                                            14
73/09/18       0010                         14.0       10.0
74/05/20       0003                         11.0       11.2        1.2
74/05/20       0007                         11.0       11.2                             4.5         11         11
74/05/20       0013                         11.0       11.2
74/06/03       0003                         13.5       10.6        1.5
74/06/03       0007                                                                     8.6          9          2
74/06/03       0013                         13.5       10.7
74/07/09       0003                         21.0        8.3        1.8
74/07/09       0007                                                          4.1                     8          3
74/07/09       0010                         21.0        7.8
74/07/09       0016                         16.0        4.3
74/08/12       0003                         19.0        7.9        1.8
74/08/12       0007                         19.0        7.9                  3.3                     9        0.4
74/08/12       0013                         19.0        7.7
74/08/12       0016                         17.0        4.7
74/09/04       0003                         18.0        9.3        1.5
74/09/04       0007                                                          5.3                     9          9
74/09/04       0010                         17.0        7.3

                                                                        053031          4290AC053031
                                                                       44 36 43.0 087 58 21.0
                                                                       GREEN BAY OPEN WATER UNK STA 17
                                                                       55      WISCONSIN
                                                                       LAKE MICHIGAN

                                                                       21WIS                2111202
                                                                       2                    0009 FEET  DEPTH

                       00671     00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH PHOS-DIS   PHOS-TOT    ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM     OF         ORTHO                   N         DISS       DISS       TOTAL     A UG/L        A
   TO     DAY  FEET   MG/L P     MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

73/09/18       0007    0.003      0.033      0.200       0.04      0.002      0.133      15.00       1.00
74/05/20       0007    0.004      0.049      0.400       0.09      0.011      0.250       1.50
74/06/03       0007    0.008      0.060      1.000       0.06      0.003      0.040       9.30       1.80
74/07/09       0007    0.005      0.044      0.300       0.03      0.001      0.040      10.40       2.80
74/08/12       0007    0.011      0.033      0.600       0.06      0.011      0.010K      0.80      25.00
74/09/04       0007    0.011      0.056      0.100       0.09      0.003      0.060      10.10      19.20
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STORET RETRIEVAL DATE 75/06/06
                                                           053032         429UAC053032
                                                          44 38 10.0 087 57 39.0
                                                          GREEN BAY OPEN WATER DNR STA 18
                                                          55      WISCONSIN
                                                          LAKE MICHIGAN

                                                          21WIS                2111202
                                                          2                    0016 FEET  DEPTH

                         72028     72029      00010     00299     00076     00310     00312     00940     00530
  DATE    TIME DEPTH  AZIMUTH   DISTANCE     WATER       DO      TRANSP     BOD       BOD     CHLORIDE  RESIDUE
  FROM     OF         FR SOUTH  FR SOUTH     TEMP      PROBE     SECCHI    5 DAY     6 DAY       CL     TOT NFLT
   TO     DAY  FEET   DEGREES     FEET       CENT       MG/L     METERS     MG/L      MG/L      MG/L      MG/L

73/09/18       0003                          14.5        9.8       1.3
73/09/18       0007                                                                                        23
73/09/18       0010                          14.3        9.4
73/09/18       0020                          14.0        9.0
74/02/18       0003                           1.1       18.5
74/02/18       0013                           2.0       16.2
74/05/20       0003                          10.0       11.3       1.5
74/05/20       0007                          10.0       11.3                           3.7        10         7
74/05/20       0010                          10.0       11.5
74/05/20       0020                          10.0       11.0
74/06/03       0003                          13.0       10.4       1.8
74/06/03       0007                                                                    8.6         8       0.4
74/06/03       0010                          13.0       10.5
74/06/03       0016                          13.0       10.4
74/07/09       0003                          21.5        8.6       1.5
74/07/09       0007                                                          3.3                   8         3
74/07/09       0010                          21.0        8.2
74/07/09       0016                          16.0        5.3
74/08/12       0003                          20.0        7.5       0.9
74/08/12       0007                                                          4.9                  11         1
74/08/12       0010                          20.0        7.3
74/08/12       0018                          19.0        6.8
74/09/04       0003                          19.0        8.8       1.6
74/09/04       0007                                                          4.1                   8        10
74/09/04       0013                          17.0        8.1


                                                           053032         429UAC053032
                                                          44 38 10.0 087 57 39.0
                                                          GREEN BAY OPEN WATER DNR STA 18
                                                          55      WISCONSIN
                                                          LAKE MICHIGAN

                                                          21WIS                2111202
                                                          2                    0016 FEET  DEPTH

                        00671     00665     00605     00618     00613     00610     32211     32218
  DATE    TIME DEPTH PHOS-DIS   PHOS-TOT    ORG N     NO3-N     NO2-N     NH3-N   CHLRPHYL  PHEOPHTN
  FROM     OF          ORTHO                  N        DISS      DISS     TOTAL    A UG/L       A
   TO     DAY  FEET   MG/L P     MG/L P     MG/L      MG/L      MG/L      MG/L    CORRECTD    UG/L

73/09/18       0007    0.009     0.029     0.200      0.04     0.002     0.195     10.00      5.00
74/05/20       0007    0.006     0.032     0.100      0.10     0.011     0.260
74/06/03       0007    0.010     0.050     0.800      0.06     0.002     0.030
74/07/09       0007    0.006     0.040     0.300      0.03     0.004     0.030
74/08/12       0007    0.005     0.037     0.700      0.06     0.006     0.010K
74/09/04       0007    0.019     0.048     0.300      0.07     0.002     0.090
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STORET RETRIEVAL DATE 75/06/06

053033 4290AC053033
44 38 26.0 087 59 07.0
GREEN BAY OPEN WATER DNR STA 19
55 WISCONSIN
LAKE MICHIGAN

21WIS 2111202
2 0013 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	72028 AZIMUTH FR SOUTH DEGREES	72029 DISTANCE FR SOUTH FEET	00010 WATER TEMP CENT	00299 DO PROBE MG/L	00078 TRANSP SECCHI METERS	00310 BOD 5 DAY MG/L	00312 BOD 6 DAY MG/L	00940 CHLORIDE CL MG/L	00530 RESIDUE TOT NFLT MG/L
73/09/18		0003			14.3	9.6	1.0				
73/09/18		0007									
73/09/18		0010			14.0	9.6					
73/09/18		0013			13.5	9.3					
74/06/03		0003			14.0	10.4	1.5				
74/06/03		0010			14.0	10.5					
74/06/03		0016			14.0	10.6					
74/07/09		0003			21.0	8.4	1.5				
74/07/09		0007			21.0	8.1					
74/07/09		0013			16.5	3.8					
74/08/12		0003			21.0	8.8	1.0				
74/08/12		0007			21.0	8.7					
74/08/12		0013			20.0	7.7					
74/09/04		0003			19.0	9.1	1.3				
74/09/04		0010			18.0	9.4					

053033 4290AC053033
44 38 26.0 087 59 07.0
GREEN BAY OPEN WATER DNR STA 19
55 WISCONSIN
LAKE MICHIGAN

21WIS 2111202
2 0013 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	00605 ORG N N MG/L	00618 NO3-N DISS MG/L	00613 NO2-N DISS MG/L	00610 NH3-N TOTAL MG/L	32211 CHLRPHYL A UG/L CORRECTD	32210 PHEOPHTN A UG/L
73/09/18		0007	0.005	0.032	0.300	0.04	0.003	0.133	15.00	2.00

```
STORET RETRIEVAL DATE 75/06/06
                                                                     053034          4290AC053034
                                                                     44 37 14.0 087 59 21.0
                                                                     GREEN BAY OPEN WATER DNR STA 21
                                                                     55       WISCONSIN
                                                                     LAKE MICHIGAN

                                                                     21A15                    2111202
                                                                     2                       0009 FEET  DEPTH

                         72028     72029     00010     00299     00078     00310     00312    00940     00530
  DATE    TIME DEPTH   AZIMUTH  DISTANCE    WATER       DO      TRANSP     BOD       BOD    CHLORIDE  RESIDUE
  FROM     OF         FR SOUTH  FR SOUTH    TEMP      PROBE     SECCHI    5 DAY     6 DAY      CL     TOT NFLT
   TO     DAY  FEET   DEGREES     FEET      CENT      MG/L      METERS    MG/L      MG/L      MG/L      MG/L

73/09/18        0003                         14.5      10.0       0.9
73/09/18        0007                                                                                      20
73/09/18        0010                         14.5      10.0
74/06/03        0003                         13.0      11.0       1.5
74/06/03        0010                         13.0      10.8
74/07/09        0003                         21.0       7.3       1.5
74/07/09        0010                         20.0       6.1
74/08/12        0003                         21.0       8.6       0.8
74/08/12        0007                         20.5       8.3
74/08/12        0013                         19.5       6.8
74/09/04        0003                         18.0       9.1       1.2
74/09/04        0010                         17.0       8.3


                                                                     053034          4290AC053034
                                                                     44 37 14.0 087 59 21.0
                                                                     GREEN BAY OPEN WATER DNR STA 21
                                                                     55       WISCONSIN
                                                                     LAKE MICHIGAN

                                                                     21A15                    2111202
                                                                     2                       0009 FEET  DEPTH

                        00671     00664     00605     00618     00613     00610     32211     32218
  DATE    TIME DEPTH  PHOS-DIS  PHOS-TOT    ORG N     NO3-N     NO2-N     NH3-N    CHLRPHYL  PHEOPHTN
  FROM     OF           ORTHO                 N       DISS      DISS      TOTAL    A UG/L       A
   TO     DAY  FEET    MG/L P    MG/L P     MG/L      MG/L      MG/L      MG/L     CORRECTD    UG/L

73/09/18        0007     0.005     0.040     0.400      0.04     0.003     0.145     18.00       4.00
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                         433006         4290AC433006
                                                                        44 41 44.0 087 58 29.0
                                                                        GREEN BAY OPEN WATER DNR STA 23
                                                                        55      WISCONSIN
                                                                        LAKE MICHIGAN

                                                                        21615                2111202
                                                                        2                    0006 FEET  DEPTH

                            72028     72029      00010     00299     00076     00310     00312     00940     00530
 DATE    TIME DEPTH   AZIMUTH   DISTANCE    WATER      DO      TRANSP     BOD       BOD     CHLORIDE  RESIDUE
 FROM     OF          FR SOUTH  FR SOUTH    TEMP     PROBE     SECCHI    5 DAY     6 DAY      CL     TOT NFLT
  TO     DAY   FEET   DEGREES     FEET      CENT      MG/L     METERS     MG/L      MG/L      MG/L      MG/L

73/09/18        0003                        13.7       9.6       1.2
73/09/18        0007                                                                                     15
73/09/18        0010                        13.7       9.4
74/05/20        0003                        10.0      12.2       1.8
74/05/20        0013                         9.5      11.6
74/06/04        0003                        13.5      10.2       1.9
74/06/04        0013                        13.0      10.2
74/07/09        0003                        19.0       6.8       1.8
74/07/09        0010                        18.0       5.1
74/08/12        0003                        22.0       9.4       0.9
74/08/12        0007                        22.0       9.3
74/08/12        0010                        22.0       9.3
74/09/04        0003                        18.0       9.3       1.5
74/09/04        0010                        17.0       9.7


                                                                         433006         4290AC433006
                                                                        44 41 44.0 087 58 29.0
                                                                        GREEN BAY OPEN WATER DNR STA 23
                                                                        55      WISCONSIN
                                                                        LAKE MICHIGAN

                                                                        21615                2111202
                                                                        2                    0006 FEET  DEPTH

                        00671     00665     00605     00618     00613     00610     32211     32218
 DATE    TIME DEPTH  PHOS-DIS  PHOS-TOT    ORG N     NO3-N     NO2-N     NH3-N    CHLRPHYL  PHEOPHTN
 FROM     OF           ORTHO                 N        DISS      DISS     TOTAL    A UG/L       A
  TO     DAY   FEET   MG/L P    MG/L P     MG/L      MG/L      MG/L      MG/L    CORRECTD    UG/L

73/09/18        0007    0.007     0.034     0.600      0.03     0.001     0.027     13.00      1.00
```

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STORET RETRIEVAL DATE 75/06/06
                                                          433007          4290AC433007
                                                          44 41 06.0 087 56 06.0
                                                          GREEN BAY OPEN WATER DNR STA 24
                                                          55      WISCONSIN
                                                          LAKE MICHIGAN

                                                          21WIS                2111202
                                                          2                    0019 FEET  DEPTH

                          72028     72029     00010     00299     00078     00310     00312     00940     00530
  DATE   TIME DEPTH     AZIMUTH   DISTANCE    WATER       DO     TRANSP      BOD       COD     CHLORIDE  RESIDUE
  FROM    OF           FR SOUTH   FR SOUTH    TEMP      PROBE    SECCHI     5 DAY     6 DAY      CL     TOT NFLT
   TO    DAY  FEET     DEGREES      FEET      CENT      MG/L     METERS     MG/L      MG/L      MG/L      MG/L

73/09/18      0003                            14.0       9.5      1.2
73/09/18      0007                                                                                          25
73/09/18      0010                            14.0       9.5
73/09/18      0020                            14.0       9.5
74/02/18      0007                             1.9      18.6                1.8                  9         4
74/02/18      0016                             1.1      18.6
74/05/20      0003                             9.0      11.8      1.8
74/05/20      0007                             9.0      11.8                          3.7        9         6
74/05/20      0010                             8.5      11.8
74/05/20      0020                             8.0      12.0
74/06/04      0003                            12.0      10.4      1.9
74/06/04      0007                                                                               9         1
74/06/04      0014                            12.0      10.3
74/06/04      0023                            12.0      10.4
74/07/09      0003                            21.0       8.8      1.6
74/07/09      0007                                                          4.5                  8         2
74/07/09      0010                            20.0       8.1
74/07/09      0020                            19.0       5.8
74/08/12      0003                            19.0       8.3      1.5
74/08/12      0007                            19.0       8.3                5.3                 10       0.1K
74/08/12      0013                            19.0       7.9
74/08/12      0016                            18.0       7.4
74/08/12      0020                            15.0       5.2
74/09/04      0003                            19.0       8.2      1.8
74/09/04      0007                                                          4.1                  9         3
74/09/04      0010                            17.0       7.8
74/09/04      0023                            17.0       7.6

                                                          433007          4290AC433007
                                                          44 41 06.0 087 56 06.0
                                                          GREEN BAY OPEN WATER DNR STA 24
                                                          55      WISCONSIN
                                                          LAKE MICHIGAN

                                                          21WIS                2111202
                                                          2                    0019 FEET  DEPTH

                         00671     00665     00605     00618     00613     00610     32211     32218
  DATE   TIME DEPTH    PHOS-DIS  PHOS-TOT    ORG N    NO3-N     NO2-N     NH3-N    CHLRPHYL  PHEOPHTN
  FROM    OF            ORTHO                  N       DISS      DISS      TOTAL    A UG/L       A
   TO    DAY  FEET     MG/L P    MG/L P     MG/L      MG/L      MG/L      MG/L    CORRECTD    UG/L

73/09/18      0007     0.005     0.034     0.200      0.03     0.003     0.020     15.00      1.00
74/02/18      0007     0.004     0.019     0.100      0.02     0.007     0.131
74/05/20      0007     0.006     0.037     0.100      0.10     0.012     0.180      9.90
74/06/04      0007     0.005     0.050     0.300      0.01     0.007     0.080      5.70      2.30
74/07/09      0007     0.012     0.044     0.300      0.03     0.009     0.090      6.70      3.80
74/08/12      0007     0.006     0.016     0.600      0.07     0.005     0.010K     0.00     39.80
74/09/04      0007     0.011     0.033     0.300      0.06     0.002     0.010     16.70      0.00
```

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STORET RETRIEVAL DATE 75/06/06
                                                                433008          4290AC433008
                                                                44 44 54.0 087 55 07.0
                                                                GREEN BAY OPEN WATER DNR STA 25
                                                                55      WISCONSIN
                                                                LAKE MICHIGAN

                                                                21WIS               2111202
                                                                2                   0006 FEET  DEPTH

                             72028      72029      00010      00299      00078      00310      00312      00940      00530
  DATE    TIME DEPTH   AZIMUTH   DISTANCE    WATER        DO      TRANSP      BOD        BOD     CHLORIDE   RESIDUE
  FROM     OF          FR SOUTH  FR SOUTH    TEMP      PROBE     SECCHI     5 DAY      6 DAY        CL      TOT NFLT
   TO     DAY   FEET   DEGREES     FEET      CENT       MG/L     METERS      MG/L       MG/L       MG/L       MG/L

73/09/18        0003                          13.0       10.0        0.9
73/09/18        0007                                                                                           10
74/05/20        0003                          10.0       11.7        1.8
74/05/20        0010                           9.0       12.2
74/06/04        0003                          13.5       10.4        1.9
74/06/04        0007                          13.5       10.5
74/07/09        0003                          20.0        7.6        1.3
74/08/13        0003                          21.0        8.2        1.0
74/08/13        0013                          19.0        8.1
74/09/05        0003                          17.0       10.8        1.5
74/09/05        0010                          17.0       10.8


                                                                433008          4290AC433008
                                                                44 44 54.0 087 55 07.0
                                                                GREEN BAY OPEN WATER DNR STA 25
                                                                55      WISCONSIN
                                                                LAKE MICHIGAN

                                                                21WIS               2111202
                                                                2                   0006 FEET  DEPTH

                           00671      00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH   PHOS-DIS    PHOS-TOT    ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM     OF           ORTHO                    N         DISS       DISS      TOTAL      A UG/L        A
   TO     DAY   FEET   MG/L P      MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD      UG/L

73/09/18        0007    0.006      0.040      0.600       0.03      0.001      0.041       8.00       4.00
```

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STORET RETRIEVAL DATE 75/06/06
                                                                     433009        429UAC433009
                                                                     44 42 46.0 087 51 00.0
                                                                     GREEN BAY OPEN WATER DNR STA 26
                                                                     55      WISCONSIN
                                                                     LAKE MICHIGAN

                                                                     21615                2111202
                                                                     2                    0029 FEET  DEPTH

                            72028      72029       00010      00299     0007K      00310     00312     00940     00530
  DATE     TIME DEPTH    AZIMUTH   DISTANCE     WATER        DO      TRANSP      BOD       BOD     CHLORIDE  RESIDUE
  FROM      OF          FR SOUTH  FR SOUTH      TEMP      PROBE     SECCHI     5 DAY     6 DAY       CL     TOT NFLT
   TO      DAY   FEET    DEGREES     FEET       CENT       MG/L     METERS      MG/L      MG/L      MG/L      MG/L

73/09/18        0003                             15.0       9.2       1.3
73/09/18        0007                                                                                              13
73/09/18        0010                             15.0       9.2
73/09/18        0020                             15.0       9.0
73/09/18        0030                             15.0       8.8
74/02/20        0003    315.0     5000.0          0.0      12.8
74/02/20        0006                              0.0      12.9
74/02/20        0010    315.0     5000.0          0.0      12.8
74/02/20        0012                              0.1      11.9
74/02/20        0020    315.0     5000.0          0.3      10.7
74/02/20        0025                              0.1       8.1
74/02/20        0030    315.0     5000.0          1.0       9.5
74/02/20        0033                              1.2       3.9
74/02/20        0036    315.0     5000.0          1.0       7.7
74/05/20        0003                              8.0      12.5       1.7
74/05/20        0007                              8.0      12.5                           9.1        10         7
74/05/20        0010                              8.0      12.9
74/05/20        0020                              7.0      12.0
74/05/20        0039                              7.0      12.5
74/06/04        0003                             12.0      10.3       2.1
74/06/04        0007                                                                                  9       0.1
74/06/04        0013                             11.5      10.2
74/06/04        0023                             11.5       9.8
74/06/04        0033                              9.0       6.6                                      9         6
74/07/09        0003                             22.0       8.7       1.8
74/07/09        0007                                                            3.3                   8       0.9
74/07/09        0010                             20.0       8.5
74/07/09        0020                             19.0       8.0
74/07/09        0026                             15.0       6.2
74/07/09        0033                             12.0       5.8                 3.7                   8        18
74/08/13        0003                             19.0       8.6       1.9
74/08/13        0007                                                            5.3                   9       0.9
74/08/13        0013                             19.0       8.9
74/08/13        0026                             19.0       8.1
74/08/13        0030                             14.0       3.5
74/08/13        0033                             11.0       2.2                 4.1                   7      0.1K
74/09/05        0003                             17.0       9.9       1.9
74/09/05        0007                                                            3.3                   8         5
74/09/05        0013                             17.0      10.0
74/09/05        0033                             17.0       9.8                 4.5                   8        57
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STORET RETRIEVAL DATE 75/06/06
                                                                      433009          4290AC433009
                                                                     44 42 46.0 087 51 00.0
                                                                     GREEN BAY OPEN WATER DNR STA 26
                                                                     55      WISCONSIN
                                                                     LAKE MICHIGAN

                                                                     21WIS                  2111202
                                                                     2                      0029 FEET  DEPTH

                         00671      00665       00605      00618      00613      00610     32211      32218
  DATE    TIME DEPTH   PHOS-DIS   PHOS-TOT     ORG N      NO3-N      NO2-N      NH3-N    CHLRPHYL   PHEOPHTN
  FROM     OF            ORTHO                   N         DISS       DISS       TOTAL    A UG/L       A
   TO     DAY   FEET    MG/L P     MG/L P       MG/L       MG/L       MG/L       MG/L     CORRECTD    UG/L

73/09/18        0007    0.006      0.037       0.500       0.03      0.002      0.081     14.00       1.00
74/05/20        0007    0.006      0.050       0.200       0.13      0.015      0.210
74/06/04        0007    0.008      0.050       0.100       0.03      0.008      0.050
74/06/04        0033    0.010      0.080       0.800       0.07      0.008      0.110
74/07/09        0007    0.010      0.043       0.100K     0.005      0.005      0.010K
74/07/09        0033    0.011      0.049       0.500       0.54      0.038      0.040
74/08/13        0007    0.014      0.014       0.300       0.17      0.003      0.010K
74/08/13        0033    0.010      0.014       0.100       0.83      0.014      0.010K
74/09/05        0007    0.005      0.022       0.700       0.02      0.006      0.010
74/09/05        0033    0.006      0.334       1.000       0.08      0.008      0.080
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STORET RETRIEVAL DATE 75/06/06
                                                                                153002          429UAC153002
                                                                               44 41 42.0 087 48 30.0
                                                                               GREEN BAY OPEN WATER DNR STA 26A
                                                                               55      WISCONSIN
                                                                               LAKE MICHIGAN

                                                                               21WIS                  2111202
                                                                               2                     0029 FEET  DEPTH

                            72028     72029      00010      00299      00076     00310     00312     00940     00530
  DATE     TIME DEPTH   AZIMUTH   DISTANCE    WATER        DO       TRANSP     BOD       BOD      CHLORIDE  RESIDUE
  FROM      OF          FR SOUTH  FR SOUTH    TEMP       PROBE      SECCHI    5 DAY     6 DAY       CL      TOT NFLT
   TO      DAY   FEET   DEGREES     FEET      CENT        MG/L      METERS     MG/L      MG/L      MG/L       MG/L

74/02/20         0005     135.0    5000.0                13.3
74/02/20         0006                            0.1      11.8
74/02/20         0010     135.0    5000.0        0.3      12.8
74/02/20         0012                            0.1      11.2
74/02/20         0020     135.0    5000.0        0.4       9.3
74/02/20         0021                            0.0       7.6
74/02/20         0031     135.0    5000.0        1.2       3.3
74/02/20         0033                            1.2       4.7
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STORET RETRIEVAL DATE 75/06/06
                                                                   053035          429UAC053035
                                                                  44 40 26.0 087 45 32.0
                                                                  GREEN BAY OPEN WATER DNR STA 27
                                                                  55      WISCONSIN
                                                                  LAKE MICHIGAN

                                                                  21WIS                 2111202
                                                                  2                     0022 FEET  DEPTH

                             72028     72029     00010      00299      00078     00310     00312    00940     00530
  DATE     TIME DEPTH   AZIMUTH   DISTANCE   WATER       DO      TRANSP     BOD       BOD     CHLORIDE  RESIDUE
  FROM      OF         FR SOUTH  FR SOUTH    TEMP      PROBE     SECCHI    5 DAY     6 DAY      CL     TOT NFLT
   TO      DAY   FEET   DEGREES    FEET      CENT       MG/L     METERS     MG/L      MG/L      MG/L      MG/L

73/09/18         0003                         15.5        9.4      1.5
73/09/18         0007                                                                                        8
73/09/18         0013                         15.5        9.6
74/02/20         0003                          0.3       12.4
74/02/20         0010                          0.5       12.0
74/02/20         0020                          0.8        3.1
74/02/20         0026                          1.1        3.2
74/05/20         0003                          9.3       11.6      1.2
74/05/20         0007                          9.3       12.5                          9.5        12        14
74/05/20         0010                          9.0       11.2
74/05/20         0016                          9.0       11.5
74/06/04         0003                         14.5       10.2      1.3
74/06/04         0007                                                                             5
74/06/04         0010                         14.0       10.1
74/06/04         0020                         14.0        9.9                5.3                 15         4
74/07/09         0003                         24.0        9.7      0.9
74/07/09         0007                                                        6.5                 10         4
74/07/09         0010                         23.0        9.1
74/07/09         0023                                                        6.1                 10        11
74/08/13         0003                         20.0        8.1      1.8
74/08/13         0007                                                        5.3                  9      0.1K
74/08/13         0010                         20.0        8.1
74/08/13         0023                         20.0        7.6
74/08/13         0026                         19.0        5.8                5.7                  9         1
74/09/05         0003                         18.0        9.6      1.8
74/09/05         0007                                                        4.9                  9        15
74/09/05         0010                         18.0        9.6
74/09/05         0025                         17.0        7.4                3.3                  8        39
                                                                   053035          429UAC053035
                                                                  44 40 26.0 087 45 32.0
                                                                  GREEN BAY OPEN WATER DNR STA 27
                                                                  55      WISCONSIN
                                                                  LAKE MICHIGAN

                                                                  21WIS                 2111202
                                                                  2                     0022 FEET  DEPTH

                          00671      00665      00605      00618      00613      00610      32211      32218
  DATE     TIME DEPTH  PHOS-DIS    PHOS-TOT    ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM      OF          ORTHO                    N         DISS       DISS      TOTAL     A UG/L        A
   TO      DAY   FEET   MG/L P      MG/L P     MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

73/09/18         0007    0.006      0.030      0.700      0.03      0.001      0.067      12.00       3.00
74/05/20         0007    0.007      0.092      0.300      0.17      0.015      0.240
74/06/04         0007                                                                     9.60       4.60
74/06/04         0020    0.011      0.090      0.200      0.01      0.010      0.030
74/07/09         0007    0.011      0.056      0.500      0.02      0.006      0.020      17.60       1.40
74/07/09         0023    0.011      0.051      0.300      0.02      0.005      0.040
74/08/13         0007    0.021      0.023      0.300      0.04      0.001      0.030       0.80       3.10
74/08/13         0026    0.007      0.028      0.500      0.02      0.001K     0.010K
74/09/05         0007    0.008      0.031      0.500      0.03      0.006      0.060      15.10       0.00
74/09/05         0025    0.007      0.040      0.100K     0.08      0.009      0.150
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STORET RETRIEVAL DATE 75/06/06
                                                                     153003         4290AC153003
                                                                     44 44 31.0 087 49 12.0
                                                                     GREEN BAY OPEN WATER UWM STA 27A
                                                                     55      WISCONSIN
                                                                     LAKE MICHIGAN

                                                                     21WIS                   2111202
                                                                     2                       0036 FEET  DEPTH

                          72020      72029      00010      00299      00078      00310      00312      00940      00530
  DATE    TIME DEPTH     AZIMUTH    DISTANCE   WATER       DO        TRANSP      BOD        BOD      CHLORIDE    RESIDUE
  FROM     OF           FR SOUTH   FR SOUTH    TEMP       PROBE      SECCHI     5 DAY      6 DAY        CL      TOT NFLT
   TO     DAY  FEET      DEGREES     FEET      CENT       MG/L       METERS     MG/L       MG/L        MG/L       MG/L

74/02/20       0007                             0.0       13.2                   2.0                    *           *
74/02/20       0010                             0.1       13.0
74/02/20       0020                             0.1       12.2
74/02/20       0036                             1.0        6.7                   9.8                   10         0.5



                                                                     153003         4290AC153003
                                                                     44 44 31.0 087 49 12.0
                                                                     GREEN BAY OPEN WATER UWM STA 27A
                                                                     55      WISCONSIN
                                                                     LAKE MICHIGAN

                                                                     21WIS                   2111202
                                                                     2                       0036 FEET  DEPTH

                         00671      00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH   PHOS-DIS   PHOS-TOT     ORG N      NO3-N      NO2-N      NH3-N    CHLRPHYL   PHEOPHTN
  FROM     OF            ORTHO                   N         DISS       DISS      TOTAL     A UG/L        A
   TO     DAY  FEET     MG/L P     MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

74/02/20       0007      0.002      0.007      0.300      0.01       0.005      0.084
74/02/20       0036      0.005      0.005      0.500      0.04       0.007      0.079
```

```
STORET RETRIEVAL DATE 75/06/06

                                                                 153004         4290AC153004
                                                                44 43 29.0 087 46 46.0
                                                                GREEN BAY OPEN WATER DNR STA 27B
                                                                55      WISCONSIN
                                                                LAK  .CHIGAN

                                                                21415                   2111202
                                                                2                      0029 FEET  DEPTH

 DATE    TIME DEPTH  72028    72029     00010     00299     00078     00310     00312     00940     00530
 FROM     OF        AZIMUTH  DISTANCE   WATER       DO      TRANSP     BOD       BOD    CHLORIDE  RESIDUE
  TO     DAY  FEET  FR SOUTH FR SOUTH   TEMP      PROBE     SECCHI    5 DAY     6 DAY      CL     TOT NFLT
                    DEGREES    FEET     CENT      MG/L      METERS    MG/L      MG/L      MG/L      MG/L

74/02/20      0003                        0.1      13.3
74/02/20      0010                        0.2      13.1
74/02/20      0020                        0.3      12.2
74/02/20      0033                        1.2       9.7


                                                                 153005         4290AC153005
                                                                44 42 35.0 087 44 12.0
                                                                GREEN BAY OPEN WATER DNR STA 27C
                                                                55      WISCONSIN
                                                                LAKE MICHIGAN

                                                                21415                   2111202
                                                                2                      0022 FEET  DEPTH

 DATE    TIME DEPTH  72028    72029     00010     00299     00078     00310     00312     00940     00530
 FROM     OF        AZIMUTH  DISTANCE   WATER       DO      TRANSP     BOD       BOD    CHLORIDE  RESIDUE
  TO     DAY  FEET  FR SOUTH FR SOUTH   TEMP      PROBE     SECCHI    5 DAY     6 DAY      CL     TOT NFLT
                    DEGREES    FEET     CENT      MG/L      METERS    MG/L      MG/L      MG/L      MG/L

74/02/20      0007                        0.0      12.6                2.0                   8         5
74/02/20      0012                        0.0      12.2
74/02/20      0026                       -1.1       9.0                4.9                  16         8


                                                                 153005         4290AC153005
                                                                44 42 35.0 087 44 12.0
                                                                GREEN BAY OPEN WATER DNR STA 27C
                                                                55      WISCONSIN
                                                                LAKE MICHIGAN

                                                                21415                   2111202
                                                                2                      0022 FEET  DEPTH

 DATE    TIME DEPTH   00671     00665     00605     00618     00613     00610     32211     32218
 FROM     OF       PHOS-DIS  PHOS-TOT    ORG N     NO3-N     NO2-N     NH3-N   CHLRPHYL  PHEOPHTN
  TO     DAY  FEET   ORTHO                 N        DISS      DISS     TOTAL    A UG/L       A
                    MG/L P    MG/L P     MG/L      MG/L      MG/L      MG/L    CORRECTD    UG/L

74/02/20      0007   0.003     0.002     0.300     0.02      0.010     0.021
74/02/20      0026   0.008     0.031     0.200     0.06      0.012     0.504
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                          433010           4290AC433010
                                                                         44 49 20.0 087 54 26.0
                                                                         GREEN BAY STUDY DNR STA 28
                                                                         55      WISCONSIN
                                                                         LAKE MICHIGAN

                                                                         21WIS                  2111202
                                                                         2                      0006 FEET  DEPTH

                           72028     72029     00010     00299     00078     00310     00312     00940     00530
  DATE    TIME DEPTH  AZIMUTH   DISTANCE   WATER      DO       TRANSP     BOD       BOD     CHLORIDE  RESIDUE
  FROM     OF         FR SOUTH  FR SOUTH   TEMP      PROBE     SECCHI    5 DAY     6 DAY       CL     TOT NFLT
   TO     DAY  FEET   DEGREES     FEET     CENT      MG/L      METERS    MG/L      MG/L       MG/L      MG/L

74/05/22       0003                        18.0       6.9       0.8
74/05/22       0007                        16.0       6.4                 8.0                   6         17
74/06/04       0003                        18.0       6.2       0.9
74/06/04       0007                        16.0       5.4                 4.1                   9          6
74/07/09       0003                        22.0       5.8       0.9
74/07/09       0007                        16.0       5.2                 9.8                   9          9
74/08/13       0003                        23.0       5.5       0.9
74/08/13       0007                        21.5       4.1                 5.3                  10         11
74/09/05       0003                        17.0       8.9       1.2
74/09/05       0007                                                       6.5                  10         20


                                                                          433010           4290AC433010
                                                                         44 49 20.0 087 54 26.0
                                                                         GREEN BAY STUDY DNR STA 28
                                                                         55      WISCONSIN
                                                                         LAKE MICHIGAN

                                                                         21WIS                  2111202
                                                                         2                      0006 FEET  DEPTH

                        00671      00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH  PHOS-DIS   PHOS-TOT    ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM     OF          ORTHO                   N         DISS       DISS       TOTAL     A UG/L        A
   TO     DAY  FEET   MG/L P      MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

74/05/22       0007     0.014      0.090      0.200       0.05      0.014      0.040
74/06/04       0007     0.030      0.100      0.600       0.11      0.034      0.150
74/07/09       0007     0.012      0.103      0.700       0.20      0.016      0.030
74/08/13       0007     0.028      0.061      0.600       0.08      0.023      0.010K
74/09/05       0007     0.048      0.162      0.700       0.11      0.022      0.310
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                            433011          429UAC433011
                                                                            44 40 15.0 087 52 14.0
                                                                            GREEN BAY OPEN WATER DNR STA 29
                                                                            55      WISCONSIN
                                                                            LAKE MICHIGAN

                                                                            21WIS                 2111202
                                                                            2                     0013 FEET  DEPTH

                           72028     72029      00010      00299      00078     00310     00312     00940     00530
  DATE     TIME DEPTH    AZIMUTH   DISTANCE     WATER        DO       TRANSP      BOD       BOD     CHLORIDE   RESIDUE
  FROM      OF          FR SOUTH   FR SOUTH     TEMP       PROBE      SECCHI    5 DAY     6 DAY       CL      TOT NFLT
   TO      DAY  FEET    DEGREES      FEET       CENT        MG/L      METERS     MG/L      MG/L      MG/L       MG/L

73/09/18        0003                            13.2       10.2        1.5
73/09/18        0007
                                                                                                                17
73/09/18        0010                            13.2       10.2
74/05/22        0003                            12.0       11.8        1.9
74/05/22        0007                            12.0       12.2                  8.0                  7         10
74/05/22        0010                            10.5       12.2
74/05/22        0016                            10.0       12.2
74/06/04        0003                            14.0       10.4        2.1
74/06/04        0007
                                                                                 4.1                  6          1
74/06/04        0010                            13.0       10.4
74/06/04        0016                            12.5       10.5
74/07/09        0003                            17.5        7.6        1.5
74/07/09        0007
                                                                                 5.7                  8          7
74/07/09        0010                            13.0        6.2
74/08/13        0003                            19.0        8.1        1.3
74/08/13        0007
                                                                                 5.3                 10          3
74/08/13        0010                            16.5        5.9
74/09/05        0003                            17.0       10.8        1.6
74/09/05        0007
                                                                                 4.5                  9         12
74/09/05        0010                            17.0       10.8


                                                                            433011          429UAC433011
                                                                            44 40 15.0 087 52 14.0
                                                                            GREEN BAY OPEN WATER DNR STA 29
                                                                            55      WISCONSIN
                                                                            LAKE MICHIGAN

                                                                            21WIS                 2111202
                                                                            2                     0013 FEET  DEPTH

                          00671      00665      00605      00618      00613      00610      32211      32218
  DATE     TIME DEPTH   PHOS-DIS   PHOS-TOT     ORG N     NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM      OF           ORTHO                    N        DISS       DISS      TOTAL     A UG/L        A
   TO      DAY  FEET    MG/L P     MG/L P       MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

73/09/18        0007     0.003      0.027      0.200      0.04       0.001      0.088       6.00       5.00
74/05/22        0007     0.001      0.020      0.200      0.04       0.002      0.010
74/06/04        0007     0.010      0.060      0.200      0.01       0.010      0.010K
74/07/09        0007     0.007      0.051      0.100      0.02       0.001K     0.010K
74/08/13        0007     0.003      0.018      0.400      0.12       0.009      0.010K
74/09/05        0007     0.009      0.029      0.100K     0.02       0.007      0.080
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                                433012          4290AC433012
                                                                               44 47 01.0 087 50 12.0
                                                                               GREEN BAY OPEN WATER UWM STA 30
                                                                               55      WISCONSIN
                                                                               LAKE MICHIGAN

                                                                               21415                   2111202
                                                                               2                      0029 FEET  DEPTH

                              72028     72029      00010      00299      00078      00310      00312      00940     00530
 DATE     TIME DEPTH   AZIMUTH   DISTANCE   WATER        DO       TRANSP       BOD        BOD     CHLORIDE   RESIDUE
 FROM      OF          FR SOUTH  FR SOUTH    TEMP      PROBE      SECCHI      5 DAY      8 DAY        CL      TOT NFLT
  TO      DAY   FEET   DEGREES     FEET      CENT       MG/L      METERS      MG/L       MG/L       MG/L       MG/L

73/09/18         0003                        14.5        8.4        1.6
73/09/18         0007                                                                                              18
73/09/18         0010                        14.5        8.4
73/09/18         0020                        14.5        8.4
73/09/18         0030                        14.5        8.3
74/05/22         0003                        11.0       12.2        1.8
74/05/22         0013                         7.5       12.3
74/05/22         0030                         6.0       12.0
74/06/04         0003                        12.0       11.2        2.1
74/06/04         0010                        11.5       11.2
74/06/04         0020                        11.0       10.8
74/06/04         0030                        11.0       10.4
74/06/04         0043                         8.0        8.2
74/07/09         0003                        20.0        8.3        1.8
74/07/09         0010                        18.5        8.2
74/07/09         0016                        13.5        7.2
74/08/13         0003                        20.0        8.8        1.5
74/08/13         0010                        19.0        8.0
74/08/13         0016                        17.5        6.1
74/08/13         0020                        13.0        4.9
74/09/05         0003                        17.0        9.7        1.9
74/09/05         0010                        17.0        9.6
74/09/05         0023                        17.0        8.7
74/09/05         0033                        17.0        9.9
74/09/05         0043                        17.0        9.6



                                                                                433012          4290AC433012
                                                                               44 47 01.0 087 50 12.0
                                                                               GREEN BAY OPEN WATER UWM STA 30
                                                                               55      WISCONSIN
                                                                               LAKE MICHIGAN

                                                                               21415                   2111202
                                                                               2                      0029 FEET  DEPTH

                     00671      00665      00605      00618      00613      00610      32211      32218
 DATE   TIME DEPTH PHOS-DIS   PHOS-TOT     ORG N     NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
 FROM    OF          ORTHO                   N        DISS       DISS      TOTAL     A UG/L        A
  TO    DAY   FEET  MG/L P     MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

73/09/18       0007   0.003      0.023      0.100      0.03      0.001      0.118      9.00
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                  153006          4290AC153006
                                                                  44 45 30.0 087 47 35.0
                                                                  GREEN BAY OPEN WATER DNR STA 31
                                                                  55      WISCONSIN
                                                                  LAKE MICHIGAN

                                                                  21WIS                  2111202
                                                                  2                    0039 FEET  DEPTH

                            72028      72029      00010      00299      00078      00310      00312      00940      00530
  DATE    TIME DEPTH      AZIMUTH   DISTANCE     WATER        DO       TRANSP       BOD        BOD     CHLORIDE   RESIDUE
  FROM     OF            FR SOUTH   FR SOUTH     TEMP       PROBE      SECCHI      5 DAY      6 DAY       CL      TOT NFLT
   TO     DAY   FEET     DEGREES      FEET       CENT        MG/L      METERS       MG/L       MG/L       MG/L      MG/L

73/09/18        0003                             15.0         8.3        1.5
73/09/18        0007                                                                                                 13
73/09/18        0023                             15.0         8.3
73/09/18        0039                             15.0         8.0
74/02/20        0003                              0.0        13.0
74/02/20        0007                                                                                                  3
74/02/20        0010                              0.1        12.8
74/02/20        0023                              0.3        11.2
74/02/20        0039                              0.7        10.2
74/05/22        0003                              8.5        12.4        2.3
74/05/22        0007                              8.5        12.4                   8.6                    6          7
74/05/22        0013                              7.5        12.5
74/05/22        0030                              7.0        12.2
74/05/22        0033                              6.5        12.0                   7.4                    7          4
74/05/22        0043                              6.0        11.8
74/06/04        0003                             12.0        10.6        1.6
74/06/04        0007                                                                3.6                    4        0.4
74/06/04        0010                             11.5        10.4
74/06/04        0020                             11.5        10.2
74/06/04        0030                             11.5         9.9
74/06/04        0039                              8.0         9.0                   3.3                    9          3
74/07/09        0003                             21.0         8.7        1.8
74/07/09        0007                                                                3.7                    8          5
74/07/09        0026                             18.0         7.5
74/07/09        0039                             12.0         8.1                   2.9                    8         11
74/08/13        0003                             20.0         9.0        1.6
74/08/13        0007                                                                4.5                    8          1
74/08/13        0016                             20.0         8.4
74/08/13        0033                             18.0         7.1
74/08/13        0036                             12.0         4.6
74/08/13        0039                             11.0         4.5
74/08/13        0043                             11.0         4.8
74/08/13        0046                             11.0         4.8                   3.3                    6          1
74/09/05        0003                             17.0         9.6        1.9
74/09/05        0007                                                                2.9                    9          7
74/09/05        0023                             17.0         9.2
74/09/05        0049                             15.0         8.3                   4.5                    8         18
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STORET RETRIEVAL DATE 75/06/06
                                                                     153006          4290AC153006
                                                                    44 46 30.0 087 47 35.0
                                                                    GREEN BAY OPEN WATER DNR STA 31
                                                                    55      WISCONSIN
                                                                    LAKE MICHIGAN

                                                                    21815                2111202
                                                                    2                    0039 FEET  DEPTH

                          00671      00665      00605      00618      00613      00610      32211      32218
  DATE     TIME DEPTH  PHOS-DIS   PHOS-TOT    ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM      OF           ORTHO                  N         DISS       DISS       TOTAL     A UG/L       A
   TO      DAY   FEET   MG/L P     MG/L P     MG/L       MG/L       MG/L       MG/L      CORRECTD    UG/L

73/09/18         0007    0.003      0.034      0.000       0.04      0.003      0.118       3.00
74/02/20         0007    0.006      0.006      0.100K     0.003      0.010      0.109
74/05/22         0007    0.004      0.017      0.200       0.17      0.005      0.150       4.50        3.30
74/05/22         0033    0.005      0.017      0.300       0.24      0.005      0.030
74/06/04         0007    0.012      0.060      0.300       0.06      0.011      0.010K      5.40        3.40
74/06/04         0039    0.009      0.070      0.200       0.17      0.011      0.050
74/07/09         0007    0.005      0.048      0.100       0.03      0.003      0.010K      4.30
74/07/09         0039    0.003      0.044      0.500       0.50      0.037      0.030
74/08/13         0007    0.010      0.018      0.800       0.06      0.007      0.010K      4.20        8.40
74/08/13         0046    0.010      0.021      0.200       1.02      0.011      0.010K
74/09/05         0007    0.008      0.014      0.200       0.07      0.011      0.060      10.80        1.60
74/09/05         0049    0.006      0.135      0.100       0.96      0.019      0.060
```

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STORET RETRIEVAL DATE 75/06/06
                                                                     153007          4290AC153007
                                                                    44 44 47.0 087 45 44.0
                                                                    GREEN BAY OPEN WATER DNR STA 31A
                                                                    55      WISCONSIN
                                                                    LAKE MICHIGAN

                                                                    21WIS                 2111202
                                                                    2                     0036 FEET  DEPTH

                            72028     72029      00010     00299     00078     00310     00312     00940    00530
 DATE   TIME DEPTH  AZIMUTH   DISTANCE   WATER       DO      TRANSP     BOD       BOD     CHLORIDE  RESIDUE
 FROM    OF         FR SOUTH  FR SOUTH    TEMP      PROBE     SECCHI    5 DAY     6 DAY      CL     TOT NFLT
  TO    DAY  FEET   DEGREES     FEET      CENT      MG/L      METERS    MG/L      MG/L      MG/L     MG/L

74/02/20     0007                          0.0      12.7                 2.5                    8        3
74/02/20     0010                          0.1      12.6
74/02/20     0020                          0.1      12.4
74/02/20     0030                          0.7       9.2
74/02/20     0034                          1.1       5.6                 7.0                   10        7
```

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                                                                     153007          4290AC153007
                                                                    44 44 47.0 087 45 44.0
                                                                    GREEN BAY OPEN WATER DNR STA 31A
                                                                    55      WISCONSIN
                                                                    LAKE MICHIGAN

                                                                    21WIS                 2111202
                                                                    2                     0036 FEET  DEPTH

                     00671     00665     00605     00618     00613     00610     32211     32218
 DATE   TIME DEPTH PHOS-DIS  PHOS-TOT    ORG N     NO3-N     NO2-N     NH3-N    CHLRPHYL  PHEOPHTN
 FROM    OF         ORTHO                  N        DISS      DISS     TOTAL     A UG/L      A
  TO    DAY  FEET  MG/L P    MG/L P      MG/L      MG/L      MG/L      MG/L     CORRECTD    UG/L

74/02/20     0007   0.005     0.005     0.500      0.02     0.012     0.063
74/02/20     0034   0.013     0.013     0.100      0.04     0.015     0.184
```

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STORET RETRIEVAL DATE 75/06/06
                                                             153008          4290AC153008
                                                            44 43 51.0 087 43 58.0
                                                            GREEN BAY OPEN WATER GNW STA 32
                                                            55      WISCONSIN
                                                            LAKE MICHIGAN

                                                            21415                    2111202
                                                            2                        0029 FEET  DEPTH

                        72028     72029      00010      00299      00078      00310      00312      00940      00530
  DATE   TIME DEPTH   AZIMUTH   DISTANCE    WATER        DO       TRANSP      BOD        BOD      CHLORIDE   RESIDUE
  FROM    OF          FR SOUTH  FR SOUTH    TEMP       PROBE      SECCHI     5 DAY      6 DAY        CL      TOT NFLT
   TO    DAY  FEET    DEGREES     FEET      CENT        MG/L      METERS      MG/L       MG/L       MG/L       MG/L

73/09/18      0003                          15.5        8.6        1.5
73/09/18      0007                                                                                              12
73/09/29      0023                          15.0        8.6
74/02/20      0003                           0.0       13.0
74/02/20      0012                           0.0       12.6
74/02/20      0020                           0.5       11.6
74/02/20      0030                           1.2        9.5
74/05/22      0003                          10.5       11.6        1.0
74/05/22      0010                          10.0       11.6
74/06/04      0003                          15.0       10.0        1.0
74/06/04      0013                          14.0        9.6
74/06/04      0023                          14.0        9.5
74/07/09      0003                          23.0        9.4        0.9
74/07/09      0013                          22.5        9.6
74/07/09      0026                          21.0        8.2
74/08/13      0003                          21.0        9.0        1.5
74/08/13      0010                          21.0        8.7
74/08/13      0023                          19.0        8.3
74/08/13      0026                          15.0        3.2
74/08/13      0030                          14.0        3.2
74/09/05      0003                          18.0        9.6        1.8
74/09/05      0013                          17.0        9.0
74/09/05      0030                          17.0        9.2



                                                             153008          4290AC153008
                                                            44 43 51.0 087 43 58.0
                                                            GREEN BAY OPEN WATER GNW STA 32
                                                            55      WISCONSIN
                                                            LAKE MICHIGAN

                                                            21415                    2111202
                                                            2                        0029 FEET  DEPTH

                     00671     00665     00605     00618     00613     00610     32211     32218
  DATE   TIME DEPTH PHOS-DIS  PHOS-TOT   ORG N     NO3-N     NO2-N     NH3-N    CHLRPHYL  PHEOPHTN
  FROM    OF         ORTHO                 N       DISS      DISS      TOTAL    A UG/L       A
   TO    DAY  FEET  MG/L P    MG/L P     MG/L      MG/L      MG/L      MG/L    CORRECTD    UG/L

73/09/18      0007   0.003     0.021     0.000     0.05      0.003     0.103     7.00      3.00
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STORET RETRIEVAL DATE 75/06/06
                                                                          153009         4290AC153009
                                                                         44 47 16.0 087 40 53.0
                                                                         GREEN BAY OPEN WATER DNR STA 32A
                                                                         55      WISCONSIN
                                                                         LAKE MICHIGAN

                                                                         21WIS                   2111202
                                                                         2                       0029 FEET  DEPTH
                                72028     72029      00010      00299      00078      00310      00312      00940      00530
  DATE    TIME DEPTH  AZIMUTH  DISTANCE   WATER        DO       TRANSP      BOD        BOD      CHLORIDE   RESIDUE
  FROM     OF        FR SOUTH  FR SOUTH    TEMP      PROBE      SECCHI     5 DAY      6 DAY        CL      TOT NFLT
   TO     DAY  FEET   DEGREES    FEET      CENT       MG/L      METERS      MG/L       MG/L       MG/L       MG/L

74/02/27       0003    315.0    5000.0                14.8
74/02/27       0006                                   15.6
74/02/27       0010    315.0    5000.0                14.5
74/02/27       0012                                   14.8
74/02/27       0020    315.0    5000.0                14.2
74/02/27       0021                                    6.0
74/02/27       0026                                    7.8
74/02/27       0033    315.0    5000.0                 4.9
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STORET RETRIEVAL DATE 75/06/06
                                                          153010         4290AC153010
                                                         44 48 07.0 087 43 19.0
                                                         GREEN BAY OPEN WATER DNR STA 32B
                                                         55      WISCONSIN
                                                         LAKE MICHIGAN

                                                         21WIS                   2111202
                                                         2                      0045 FEET  DEPTH

                          72028     72029     00010     00299    00078     00310     00312    00940    00530
  DATE    TIME DEPTH    AZIMUTH   DISTANCE    WATER      DO     TRANSP      BOD       BOD    CHLORIDE  RESIDUE
  FROM     OF          FR SOUTH   FR SOUTH    TEMP     PROBE    SECCHI    5 DAY     6 DAY      CL     TOT NFLT
   TO     DAY   FEET   DEGREES      FEET      CENT      MG/L    METERS     MG/L      MG/L     MG/L      MG/L

74/02/27        0003    315.0     5000.0               15.2
74/02/27        0006                                   14.8
74/02/27        0010    315.0     5000.0               14.8
74/02/27        0012                                   14.2
74/02/27        0020    315.0     5000.0               14.6
74/02/27        0021                                   14.0
74/02/27        0030    315.0     5000.0               12.0
74/02/27        0031                                   11.2
74/02/27        0039                                    6.6
74/02/27        0043    315.0     5000.0                6.4


                                                          153011         4290AC153011
                                                         44 46 55.0 087 45 51.0
                                                         GREEN BAY OPEN WATER DNR STA 32C
                                                         55      WISCONSIN
                                                         LAKE MICHIGAN

                                                         21WIS                   2111202
                                                         2                      0049 FEET  DEPTH

                          72028     72029     00010     00299    00078     00310     00312    00940    00530
  DATE    TIME DEPTH    AZIMUTH   DISTANCE    WATER      DO     TRANSP      BOD       BOD    CHLORIDE  RESIDUE
  FROM     OF          FR SOUTH   FR SOUTH    TEMP     PROBE    SECCHI    5 DAY     6 DAY      CL     TOT NFLT
   TO     DAY   FEET   DEGREES      FEET      CENT      MG/L    METERS     MG/L      MG/L     MG/L      MG/L

74/02/27        0003                                   15.1
74/02/27        0010                                   15.0
74/02/27        0020                                   14.0
74/02/27        0030                                   12.0
74/02/27        0043                                    7.6
```

```
STORET RETRIEVAL DATE 75/06/06
                                                                             433013          4290AC433013
                                                                             44 53 32.0 087 50 07.0
                                                                             GREEN BAY STUDY DNR STA 33
                                                                             55      WISCONSIN
                                                                             LAKE MICHIGAN

                                                                             21815                 2111202
                                                                             2                     0006 FEET  DEPTH
                               72028      72029        00010       00299      00078      00310      00312      00940      00530
  DATE     TIME DEPTH  AZIMUTH   DISTANCE     WATER        DO        TRANSP      BOD        BOD      CHLORIDE   RESIDUE
  FROM      OF        FR SOUTH  FR SOUTH      TEMP       PROBE      SECCHI     5 DAY      6 DAY        CL      TOT NFLT
   TO      DAY  FEET   DEGREES     FEET       CENT        MG/L      METERS      MG/L       MG/L       MG/L       MG/L

79/05/22        0003                          16.0         9.8        0.7
79/05/22        0007                          14.0         6.8                   6.1                     9         13
79/06/04        0003                          18.0         6.0        1.2
79/06/04        0007                          17.0         6.0                   3.6                     6          2
79/07/08        0003                          27.5         6.5        1.0
79/07/08        0007                          22.0         9.0                              9.3          5          2
79/08/13        0003                          22.0         6.0        1.2
79/08/13        0007                                                             5.7                     7          5
79/08/13        0010                          16.0         3.9
79/09/05        0005                          19.0         8.9        1.2
79/09/05        0007                                                             3.3                     5          6
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- 357 -

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                                                                             433013          4290AC433013
                                                                             44 53 32.0 087 50 07.0
                                                                             GREEN BAY STUDY DNR STA 33
                                                                             55      WISCONSIN
                                                                             LAKE MICHIGAN

                                                                             21815                 2111202
                                                                             2                     0006 FEET  DEPTH
                       00671      00666      00405      00618      00613      00610      32211      32218
  DATE     TIME DEPTH PHOS-DIS   PHOS-TOT    ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM      OF         ORTHO                   N         DISS       DISS      TOTAL     A UG/L        A
   TO      DAY  FEET   MG/L P     MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

79/05/22        0007    0.009      0.062      0.300      0.60       0.032      0.410
79/06/04        0007    0.005      0.080      0.400      0.64       0.057      0.180
79/07/08        0007    0.013      0.046      3.100      1.13       0.137      0.150
79/08/13        0007    0.010      0.013      0.300      0.82       0.007      0.010K
79/09/05        0007    0.012      0.033      0.100      0.86       0.081      0.170
```

```
STORET RETRIEVAL DATE 75/06/06
                                                               433014          4290AC433014
                                                               44 53 15.0 087 48 56.0
                                                               GREEN BAY OPEN WATER DNR STA 34
                                                               55       WISCONSIN
                                                               LAKE MICHIGAN

                                                               21WIS                2111202
                                                               2                    0006 FEET  DEPTH

                         72028     72029      00010     00299     00076     00310     00312     00940     00530
  DATE   TIME DEPTH   AZIMUTH   DISTANCE    WATER       DO      TRANSP     BOD       BOD     CHLORIDE  RESIDUE
  FROM    OF         FR SOUTH  FR SOUTH     TEMP      PROBE     SECCHI    5 DAY     6 DAY       CL     TOT NFLT
   TO    DAY  FEET    DEGREES    FEET       CENT       MG/L     METERS     MG/L      MG/L      MG/L      MG/L

74/05/22      0003                          12.5      10.4       1.3
74/05/22      0010                          11.0      11.5
74/05/22      0023                           7.0      11.6
74/06/04      0003                          15.5      10.2       1.2
74/07/09      0003                          20.0       8.4       1.6
74/07/09      0010                          13.0       7.5
74/07/09      0023                          12.5       7.5
74/08/13      0003                          17.0       7.8       1.8
74/08/13      0010                          13.0       5.0
74/08/13      0016                          11.0       5.0
74/09/05      0003                          16.0      10.6       1.2
74/09/05      0010                          15.0      10.3
74/09/05      0020                          15.0       9.9
```

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                                                               433015          4290AC433015
                                                               44 52 41.0 087 49 21.0
                                                               GREEN BAY OPEN WATER DNR STA 34A
                                                               55       WISCONSIN
                                                               LAKE MICHIGAN

                                                               21WIS                2111202
                                                               2                    0003 FEET  DEPTH

                         72028     72029      00010     00299     00076     00310     00312     00940     00530
  DATE   TIME DEPTH   AZIMUTH   DISTANCE    WATER       DO      TRANSP     BOD       BOD     CHLORIDE  RESIDUE
  FROM    OF         FR SOUTH  FR SOUTH     TEMP      PROBE     SECCHI    5 DAY     6 DAY       CL     TOT NFLT
   TO    DAY  FEET    DEGREES    FEET       CENT       MG/L     METERS     MG/L      MG/L      MG/L      MG/L

74/05/22      0003                          11.5      11.7       1.6
74/05/22      0010                          11.0      11.8
74/05/22      0016                          10.0      12.2
74/06/04      0003                          16.0       9.8       1.2
74/07/09      0003                          19.0       8.9       1.8
74/08/13      0003                          18.0       9.1       1.8
74/09/05      0003                          17.0      11.0       1.6
74/09/05      0007                          17.0      11.4
```

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STORET RETRIEVAL DATE 75/08/06

                                                                                433017          429UAC433017
                                                                               44 52 09.0 087 44 28.0
                                                                               GREEN BAY OPEN WATER UNK STA 35
                                                                               55      WISCONSIN
                                                                               LAKE MICHIGAN

                                                                               21415                      2111202
                                                                               2                          0046 FEET  DEPTH

                                    72028      72029       00010      00299      00076      00310      00312      00940      00630
   DATE     TIME DEPTH  AZIMUTH   DISTANCE    WATER        DO       TRANSP       BOD        BOD      CHLORIDE   RESIDUE
   FROM      OF        FR SOUTH   FR SOUTH     TEMP       PROBE      SECCHI     5 DAY      6 DAY        CL      TOT NFLT
    TO      DAY  FEET   DEGREES     FEET       CENT       MG/L       METERS      MG/L       MG/L       MG/L       MG/L

 74/02/27        0005    135.0     5000.0                  15.8
 74/02/27        0006                                      15.9
 74/02/27        0007    135.0    10000.0                  14.6
 74/02/27        0010    135.0     5000.0                  15.2
 74/02/27        0011    135.0    10000.0                  14.2
 74/02/27        0012                                      15.5
 74/02/27        0019    135.0    10000.0                  13.2
 74/02/27        0020    135.0     5000.0                  13.0
 74/02/27        0021                                      14.0
 74/02/27        0029    135.0    10000.0                  11.6
 74/02/27        0030    135.0     5000.0                  12.2
 74/02/27        0031                                      12.6
 74/02/27        0043    135.0     5000.0                   9.0
 74/02/27        0044    135.0    10000.0                   8.8
 74/02/27        0046                                      12.2
 74/05/22        0003                           9.0        12.2        1.9
 74/05/22        0007                           9.0        12.2                   5.3                     7          6
 74/05/22        0020                           6.5        12.2
 74/05/22        0033                           6.0        12.0                   4.1                     7          7
 74/05/22        0039                           5.0        11.8
 74/06/09        0003                          12.0        10.9        2.5
 74/06/09        0007                                                             2.0                     8        0.1
 74/06/09        0010                          12.0        10.8
 74/06/09        0020                          11.0        10.8
 74/06/09        0030                           8.0        11.0
 74/06/09        0043                           7.0        10.2                   1.6                     8        0.1
 74/07/09        0003                          21.0         8.8        1.8
 74/07/09        0007                                                             4.1                     8          5
 74/07/09        0016                          19.0         8.3
 74/07/09        0033                          15.5         7.5
 74/07/09        0039                          14.0         7.4
 74/07/09        0046                          11.0         7.8                   7.8                     8          5
 74/08/13        0003                          19.5         9.4        2.1
 74/08/13        0007                                                             4.5                     8        0.4
 74/08/13        0013                          19.0         8.8
 74/08/13        0026                          16.0         7.1
 74/08/13        0030                          14.0         4.0
 74/08/13        0033                          10.5         4.8
 74/08/13        0046                           9.8         5.0                   3.3                     7          5
 74/09/05        0003                          17.0         9.2        1.9
 74/09/05        0007                                                             3.7                     8          6
 74/09/05        0023                          17.0         9.7
 74/09/05        0049                          15.0         9.7                   2.5                     7          1
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STORET RETRIEVAL DATE 75/06/06
                                                                    433017          4290AC433017
                                                                   44 52 09.0 087 44 28.0
                                                                   GREEN BAY OPEN WATER DNR STA 35
                                                                   55       WISCONSIN
                                                                   LAKE MICHIGAN

                                                                   21WIS                2111202
                                                                   2                    0045 FEET  DEPTH

                              00671     00665      00605     00618     00613     00610     32211     32218
  DATE    TIME DEPTH PHOS-DIS  PHUS-TOT   ORG N     NO3-N     NO2-N     NH3-N    CHLRPHYL  PHEOPHTN
  FROM     OF           ORTHO                N        DISS      DISS     TOTAL    A UG/L       A
   TO     DAY  FEET    MG/L P    MG/L P    MG/L      MG/L      MG/L      MG/L    CORRECTD    UG/L

74/05/22       0007    0.009     0.027     0.100     0.02     0.003     0.000
74/05/22       0033    0.009     0.030     0.400     0.38     0.002     0.002
74/06/04       0007    0.005     0.060     0.100K    0.04     0.008     0.030      6.20      0.80
74/06/04       0043    0.003     0.060     0.200     0.25     0.013     0.040
74/07/09       0007    0.005     0.040     0.100K    0.03     0.003     0.010      3.60      1.40
74/07/09       0046    0.010     0.051     0.800     0.56     0.038     0.030
74/08/13       0007    0.003     0.037     0.200     0.04     0.002     0.010K     9.10      9.50
74/08/13       0046    0.012     0.021     0.200     1.08     0.001     0.010K
74/09/05       0007    0.007     0.021     0.100     0.09     0.010     0.020      5.90      5.90
74/09/05       0049    0.003     0.020     0.100K    0.94     0.020     0.170
```

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STORET RETRIEVAL DATE 75/06/06
                                                                  153012          429UAC153012
                                                                  44 50 46.0 087 41 02.0
                                                                  GREEN BAY OPEN WATER UWM STA 36
                                                                  55      WISCONSIN
                                                                  LAKE MICHIGAN

                                                                  21WIS                  2111202 .
                                                                  2                      0055 FEET  DEPTH

                          72028     72029     00010     00299     00078     00310     00312     00940     00530
  DATE    TIME DEPTH   AZIMUTH  DISTANCE    WATER       DO      TRANSP     BOD       BOD     CHLORIDE  RESIDUE
  FROM     OF          FR SOUTH FR SOUTH    TEMP      PROBE     SECCHI    5 DAY     6 DAY      CL      TOT NFLT
   TO     DAY  FEET    DEGREES    FEET      CENT       MG/L     METERS     MG/L      MG/L     MG/L       MG/L

74/02/27       0003                                   14.6
74/02/27       0010                                   14.4
74/02/27       0020                                   12.7
74/02/27       0030                                   10.5
74/02/27       0043                                    8.2
74/05/22       0003                          7.0      12.3       2.7
74/05/22       0013                          6.5      12.4
74/05/22       0030                          6.0      12.0
74/05/22       0043                          6.0      12.0
74/06/04       0003                         11.5      11.5       2.7
74/06/04       0010                         11.0      11.7
74/06/04       0020                         10.3      11.4
74/06/04       0030                         10.0      11.2
74/06/04       0043                          8.0      10.7
74/07/09       0003                         21.0       8.8       1.6
74/07/09       0016                         20.0       8.2
74/07/09       0023                         19.8       8.3
74/07/09       0026                         19.0       8.4
74/07/09       0030                         11.0       8.5
74/07/09       0033                          9.0       8.2
74/07/09       0039                          9.0       6.2
74/07/09       0046                          9.0       6.2
74/08/13       0003                         20.5       9.2       1.5
74/08/13       0013                         20.0       8.9
74/08/13       0030                         17.0       8.9
74/08/13       0033                         10.5       9.9
74/08/13       0036                         10.5       9.9
74/08/13       0039                         10.5       4.9
74/08/13       0043                         10.5       4.9
74/09/05       0003                         17.0       9.9       1.8
74/09/05       0023                         17.0       9.6
74/09/05       0049                         17.0       9.8
                                                                  153013          429UAC153013
                                                                  44 49 30.0 087 38 35.0
                                                                  GREEN BAY OPEN WATER UWM STA 37
                                                                  55      WISCONSIN
                                                                  LAKE MICHIGAN

                                                                  21WIS                  2111202
                                                                  2                      0039 FEET  DEPTH

                          72028     72029     00010     00299     00078     00310     00312     00940     00530
  DATE    TIME DEPTH   AZIMUTH  DISTANCE    WATER       DO      TRANSP     BOD       BOD     CHLORIDE  RESIDUE
  FROM     OF          FR SOUTH FR SOUTH    TEMP      PROBE     SECCHI    5 DAY     6 DAY      CL      TOT NFLT
   TO     DAY  FEET    DEGREES    FEET      CENT       MG/L     METERS     MG/L      MG/L     MG/L       MG/L

74/02/27       0003                                   13.4
74/02/27       0010                                   13.1
74/02/27       0020                                   13.0
74/02/27       0033                                    9.1
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STORET RETRIEVAL DATE 75/06/06
                                                                    433018        4290AC433018
                                                                    44 56 02.0 087 44 51.0
                                                                    GREEN BAY OPEN WATER DNR STA 38
                                                                    55      WISCONSIN
                                                                    LAKE MICHIGAN

                                                                    21415                   2111202
                                                                    2                      0013 FEET  DEPTH

                            72028     72029      00010     00299     0007A     00310     00312     00940     00530
  DATE     TIME DEPTH    AZIMUTH   DISTANCE    WATER       DO      TRANSP      BOD       BOD     CHLORIDE  RESIDUE
  FROM      OF          FM SOUTH   FM SOUTH     TEMP     PROBE     SECCHI     5 DAY     6 DAY       CL     TOT NFLT
   TO      DAY  FEET    DEGREES      FEET       CENT      MG/L     METERS      MG/L      MG/L      MG/L      MG/L

73/09/24        0003                            13.5       9.6       1.5                                        2
73/09/24        0007
73/09/24        0010                            13.5       9.5
73/09/24        0020                            13.5       9.5
73/09/24        0023                            13.5       9.4
74/05/21        0003                             9.0      12.2       1.9                 3.3         8          8
74/05/21        0007                             9.0      12.2
74/05/21        0016                             7.0      12.2
74/06/04        0003                            13.5      10.6       2.1       2.5                   8          1
74/06/04        0007
74/06/04        0010                            13.0      10.5
74/06/04        0016                            13.0      10.5
74/07/08        0003                            20.5       9.1       1.9                 4.9         8          5
74/07/08        0007
74/07/08        0010                            19.0
74/07/08        0013                            18.0
74/07/08        0016                            15.0
74/07/08        0020                            19.9       7.4
74/08/13        0003                            17.0       8.0       1.9       4.5                   8          3
74/08/13        0007
74/08/13        0010                            15.0       7.6
74/08/13        0020                            11.0       5.6
74/09/05        0003                            16.0      10.6       1.9       4.1                   8          3
74/09/05        0007
74/09/05        0010                            15.0      10.6
74/09/05        0020                            15.0      10.6

                                                                    433018        4290AC433018
                                                                    44 56 02.0 087 44 51.0
                                                                    GREEN BAY OPEN WATER DNR STA 38
                                                                    55      WISCONSIN
                                                                    LAKE MICHIGAN

                                                                    21415                   2111202
                                                                    2                      0013 FEET  DEPTH

                         00671     00665     00605     00618     00613     00610     32211     32218
  DATE     TIME DEPTH  PHOS-DIS  PHOS-TOT    ORG N    NO3-N     NO2-N     NH3-N    CHLRPHYL  PHEOPHTN
  FROM      OF          ORTHO                  N       DISS      DISS     TOTAL    A UG/L       A
   TO      DAY  FEET   MG/L P    MG/L P      MG/L      MG/L      MG/L      MG/L    CORRECTD    UG/L

73/09/24        0007    0.002     0.008     0.100     0.001     0.000     0.030     9.00       3.00
74/05/21        0007    0.003     0.047     0.200      0.02     0.005     0.170
74/06/04        0007    0.006     0.060     0.200      0.02     0.008     0.100
74/07/08        0007    0.006     0.021     1.700      0.02     0.008     0.240
74/08/13        0007    0.012     0.028     0.300      0.26     0.001K    0.010K
74/09/05        0007    0.003     0.025     0.300K     0.28     0.017     0.100
```

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STORET RETRIEVAL DATE 75/06/06
                                                                    153019        4290AC153019
                                                                   44 53 38.0 087 40 13.0
                                                                   GREEN BAY OPEN WATER DNR STA 39
                                                                   55      WISCONSIN
                                                                   LAKE MICHIGAN

                                                                   21415                 2111202
                                                                   2                     0062 FEET  DEPTH

                              72028      72029      00010      00299      00078      00310      00312      00940      00530
  DATE    TIME DEPTH  AZIMUTH   DISTANCE    WATER       DO       TRANSP      BOD        BOD      CHLORIDE   RESIDUE
  FROM     OF        FR SOUTH  FR SOUTH     TEMP      PROBE      SECCHI     5 DAY      6 DAY        CL      TOT NFLT
   TO     DAY  FEET  DEGREES     FEET       CENT       MG/L      METERS      MG/L       MG/L       MG/L       MG/L

73/09/24       0003                         14.0        9.8        1.9
73/09/24       0007                                                                                             7
73/09/24       0010                         14.0        9.7
73/09/24       0020                         14.0        9.7
73/09/24       0030                         14.0        9.7
73/09/24       0039                         14.0        9.7
73/09/24       0049                         13.5        9.6
74/05/21       0003                          8.0       12.0        2.4
74/05/21       0010                          7.0       12.0
74/05/21       0020                          6.0       11.6
74/05/21       0030                          6.0       11.6
74/05/21       0043                          6.0       11.8
74/06/04       0003                         12.5       11.0        2.4
74/06/04       0010                         12.0       11.2
74/06/04       0020                         10.5       11.8
74/06/04       0030                         10.0       11.6
74/06/04       0043                          8.0       10.8
74/07/08       0003                         20.5        8.8        2.4
74/07/08       0023                         17.0        7.6
74/07/08       0047                         13.0        7.4
74/08/13       0003                         19.0        9.2        2.4
74/08/13       0016                         16.0        7.9
74/08/13       0033                         13.0        6.1
74/08/13       0048                         10.0        6.0
74/09/05       0003                         17.0        9.2        2.1
74/09/05       0023                         16.0        9.6
74/09/05       0049                         16.0        9.3


                                                                    153019        4290AC153019
                                                                   44 53 38.0 087 40 13.0
                                                                   GREEN BAY OPEN WATER DNR STA 39
                                                                   55      WISCONSIN
                                                                   LAKE MICHIGAN

                                                                   21415                 2111202
                                                                   2                     0062 FEET  DEPTH

                          00671      00666      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH   PHOS-DIS   PHOS-TOT     ORG N     NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM     OF            ORTHO                   N        DISS       DISS       TOTAL     A UG/L        A
   TO     DAY  FEET     MG/L P     MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

73/09/24       0007      0.003      0.012      0.100      0.04       0.003      0.030      6.00       3.00
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STORET RETRIEVAL DATE 75/06/06
                                                                                 153015          4290AC153015
                                                                                 44 51 18.0 087 35 55.0
                                                                                 GREEN BAY OPEN WATER DNR STA 40
                                                                                 55      WISCONSIN
                                                                                 LAKE MICHIGAN

                                                                                 21W15                 2111202
                                                                                 2                     0052 FEET  DEPTH

                            72028     72029      00010      00299      00078      00310      00312      00940      00530
  DATE    TIME DEPTH     AZIMUTH   DISTANCE     WATER        DO       TRANSP       BOD        BOD     CHLORIDE   RESIDUE
  FROM     OF           FR SOUTH   FR SOUTH     TEMP       PROBE      SECCHI      5 DAY      6 DAY        CL      TOT NFLT
   TO     DAY   FEET     DEGREES     FEET       CENT        MG/L      METERS       MG/L       MG/L       MG/L       MG/L

73/09/24        0003                            14.5        10.7        1.5
73/09/24        0007                                                                                                3
73/09/24        0010                            14.5         9.5
73/09/24        0020                            14.5         9.1
73/09/24        0030                            14.0         8.7
73/09/24        0039                            14.0         8.4
73/09/24        0049                            14.0         8.3
74/05/21        0003                             8.0        12.2        1.9
74/05/21        0007                             8.0        12.2                               3.3         10       9
74/05/21        0013                             6.3        12.0
74/05/21        0030                             6.3        12.1
74/05/21        0043                             6.5        11.5                               3.7         10       9
74/06/04        0003                            14.0        10.5        1.6
74/06/04        0007                                                               2.5                      9      26
74/06/04        0010                            13.0        10.4
74/06/04        0020                            12.0        10.8
74/06/04        0030                            12.0        10.8
74/06/04        0043                            12.0        10.7                   3.3                      7     0.1
74/07/08        0003                            22.0         9.8        1.2
74/07/08        0007                                                                          5.5         10       2
74/07/08        0023                            19.0         8.4
74/07/08        0046                            10.0         7.5                              3.1          8       1
74/08/13        0003                            19.0         9.4        2.1
74/08/13        0007                                                               4.9                      9       4
74/08/13        0016                            18.5         8.6
74/08/13        0033                            14.5         6.2
74/08/13        0046                            10.0         4.3                   3.7                      7       4
74/09/05        0003                            17.0        10.1        1.9
74/09/05        0007                                                               3.3                      9       6
74/09/05        0015                            17.0         9.6
74/09/05        0030                            17.0         9.2
74/09/05        0049                            16.0         4.8                   2.5                      8      12
```

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STORET RETRIEVAL DATE 75/06/06
                                                                          153015          4290AC153015
                                                                          44 51 18.0 087 35 55.0
                                                                          GREEN BAY OPEN WATER DNR STA 40
                                                                          55      WISCONSIN
                                                                          LAKE MICHIGAN

                                                                          21WIS                 2111202
                                                                          2                     0052 FEET  DEPTH

                           00671       00665       00605      00618      00613      00610      32211      32218
 DATE      TIME DEPTH PHOS-DIS    PHOS-TOT     ORG N      NO3-N      NO2-N      NH3-N    CHLRPHYL   PHEOPHTN
 FROM       OF          ORTHO                    N         DISS       DISS       TOTAL     A UG/L        A
  TO       DAY  FEET   MG/L P      MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

73/09/24        0007    0.002       0.005      0.100       0.04      0.002      0.046       5.00       4.00
74/05/21        0007    0.006       0.017      0.100       0.11      0.009      0.240
74/05/21        0043    0.020       0.024      0.100       0.30      0.009      0.100
74/06/04        0007    0.012       0.120      1.000       0.27      0.013      0.100
74/06/04        0043    0.019       0.070      0.200       0.03      0.009      0.250
74/07/08        0007    0.009       0.047      0.700       0.01      0.006      0.000
74/07/08        0046    0.010       0.024      1.200       0.36      0.038      0.000
74/08/13        0007    0.007       0.059      0.300       0.03      0.004      0.010K
74/08/13        0046    0.007       0.017      0.200       1.05      0.001K     0.010K
74/09/05        0007    0.003       0.017      0.100K      0.07      0.006      0.120
74/09/05        0049    0.002       0.037      0.100K      0.91      0.029      0.110
```

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STORET RETRIEVAL DATE 75/06/06
                                                                          383003          4290AC383003
                                                                         44 58 25.0 087 39 15.0
                                                                         GREEN BAY STUDY DNR STA 41
                                                                         55      WISCONSIN
                                                                         LAKE MICHIGAN

                                                                         21WIS                2111202
                                                                         2                    0009 FEET  DEPTH

                              72028     72029     00010     00299     00078     00310     00312     00940     00530
 DATE    TIME DEPTH  AZIMUTH  DISTANCE  WATER       DO      TRANSP     BOD       BOD     CHLORIDE  RESIDUE
 FROM     OF        FR SOUTH FR SOUTH   TEMP      PROBE     SECCHI    5 DAY     4 DAY       CL     TOT NFLT
  TO     DAY  FEET  DEGREES    FEET     CENT      MG/L      METERS    MG/L      MG/L      MG/L      MG/L

74/05/21      0003                      15.0       5.7       0.8
74/05/21      0007                      15.0       5.7                           7.0         3        11
74/05/21      0010                      15.0       6.0
74/06/04      0007                      17.5       5.2       1.0       4.1                   2         1
74/07/08      0003                      25.0       1.5       1.2
74/07/08      0007                                                               7.4         5         2
74/07/08      0010                      25.0       1.7
74/08/13      0003                      22.0       3.8       1.2
74/08/13      0007                                                     4.1                   3         4
74/08/13      0010                      17.0       5.7
74/09/05      0003                      19.0       6.1       1.2
74/09/05      0007                      18.0       6.0                                                 5
```

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                                                                          383003          4290AC383003
                                                                         44 58 25.0 087 39 15.0
                                                                         GREEN BAY STUDY DNR STA 41
                                                                         55      WISCONSIN
                                                                         LAKE MICHIGAN

                                                                         21WIS                2111202
                                                                         2                    0009 FEET  DEPTH

                      00671     00665     00605     00618     00613     00610     32211     32218
 DATE    TIME DEPTH PHOS-DIS  PHOS-TOT    ORG N    NO3-N     NO2-N     NH3-N    CHLRPHYL  PHEOPHTN
 FROM     OF         ORTHO                  N       DISS      DISS     TOTAL     A UG/L       A
  TO     DAY  FEET   MG/L P    MG/L P     MG/L      MG/L      MG/L      MG/L    CORRECTD     UG/L

74/05/21      0007              0.026    0.100K     0.03     0.018     0.260
74/06/04      0007    0.005     0.070    0.100      0.05     0.017     0.070
74/07/08      0007    0.019     0.047    0.500      0.01     0.026     0.020
74/08/13      0007    0.024     0.032    0.300      0.13     0.004     0.010K
74/09/05      0007    0.005     0.033    0.300      0.34     0.019     0.017
```

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STORET RETRIEVAL DATE 75/06/06
                                                                           383009          429UAC383009
                                                                          44 57 05.0 087 39 16.0
                                                                          GREEN BAY OPEN WATER DNR STA 42
                                                                          55      WISCONSIN
                                                                          LAKE MICHIGAN

                                                                          21WIS                   2111202
                                                                          2                       0036 FEET  DEPTH

                          72028     72029      00010      00299      00078      00310      00312      00940      00530
  DATE    TIME DEPTH    AZIMUTH   DISTANCE    WATER        DO       TRANSP      BOD        BOD      CHLORIDE   RESIDUE
  FROM     OF          FR SOUTH   FR SOUTH    TEMP       PROBE      SECCHI     5 DAY      6 DAY        CL      TOT NFLT
   TO     DAY   FEET   DEGREES      FEET      CENT        MG/L      METERS      MG/L       MG/L       MG/L       MG/L

73/09/24        0003                          13.5        9.3        2.1
73/09/24        0007                                                                                              9
73/09/24        0010                          13.5        9.3
73/09/24        0020                          13.5        9.3
73/09/24        0030                          13.5        9.2
74/05/21        0003                           7.5       12.2        2.5
74/05/21        0013                           5.0       12.0
74/05/21        0030                           5.0       11.9
74/05/21        0043                           5.0       11.2
74/06/09        0003                          13.0       10.8        1.9
74/06/09        0010                          12.0       10.7
74/06/09        0020                           6.0       10.2
74/06/09        0030                           5.0       10.4
74/06/09        0045                           5.0       10.2
74/07/08        0003                          20.0       10.5        1.8
74/07/08        0017                          12.5        9.5
74/07/08        0030                          11.0        7.2
74/08/13        0003                          18.5        9.1        1.6
74/08/13        0016                          16.0        7.7
74/08/13        0030                          11.5        6.6
74/09/05        0003                          17.0       10.2        1.9
74/09/05        0020                          15.0        8.8
74/09/05        0039                          14.0        7.9


                                                                           383009          429UAC383009
                                                                          44 57 05.0 087 39 16.0
                                                                          GREEN BAY OPEN WATER DNR STA 42
                                                                          55      WISCONSIN
                                                                          LAKE MICHIGAN

                                                                          21WIS                   2111202
                                                                          2                       0036 FEET  DEPTH

                        00671      00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH  PHOS-DIS   PHOS-TOT     ORG N     NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM     OF          ORTHO                    N        DISS       DISS      TOTAL     A UG/L        A
   TO     DAY   FEET   MG/L P     MG/L P      MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

73/09/24        0007    0.002      0.003      0.100      0.03      0.001      0.001       4.00       9.00
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STORET RETRIEVAL DATE 75/06/06
                                                                        153016          4290AC153016
                                                                        44 55 08.0 087 36 37.0
                                                                        GREEN BAY OPEN WATER UNH STA 43
                                                                        55      WISCONSIN
                                                                        LAKE MICHIGAN

                                                                        21015                     2111202
                                                                        2                         0065 FEET  DEPTH

                            72028     72029      00010     00299     00078     00310     00312    00940     00530
  DATE     TIME DEPTH     AZIMUTH   DISTANCE     WATER       DO      TRANSP     BOD       BOD    CHLORIDE  RESIDUE
  FROM      OF           FR SOUTH   FR SOUTH     TEMP      PROBE     SECCHI    5 DAY     6 DAY      CL     TOT NFLT
   TO      DAY  FEET     DEGREES      FEET       CENT      MG/L      METERS    MG/L      MG/L      MG/L      MG/L

73/09/24        0003                              14.0       8.7       2.1
73/09/24        0007                                                                                          3
73/09/24        0020                              14.0       8.7
73/09/24        0039                              14.0       8.7
73/09/24        0049                              13.0       8.7
74/05/21        0003                               8.0      12.2       2.5
74/05/21        0007                               8.0      12.2                           2.9        8        9
74/05/21        0013                               6.5      12.2
74/05/21        0030                               5.0      11.8
74/05/21        0043                               4.5      11.8
74/05/21        0059                               4.5      11.8                           3.7        9        7
74/06/04        0003                              13.0      11.2       2.5
74/06/04        0007                                                             2.9                  7        1
74/06/04        0010                              12.5      11.2
74/06/04        0020                              10.0      11.3
74/06/04        0030                               7.0      11.2
74/06/04        0043                               6.5      11.2
74/07/08        0003                              20.0       9.0       1.6
74/07/08        0007                                                             2.6                  8      0.9
74/07/08        0023                              17.0       7.4
74/07/08        0046                              12.0       9.5
74/08/13        0003                              18.0       9.0       2.3
74/08/13        0007                                                             4.6                  8        4
74/08/13        0016                              16.5       8.1
74/08/13        0030                              12.5       6.7
74/08/13        0046                               9.0       7.6
74/09/05        0003                              18.0       9.5       2.1
74/09/05        0007                                                             4.9                  8        2
74/09/05        0025                              16.0       9.5
74/09/05        0050                              13.0       7.5
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STORET RETRIEVAL DATE 75/06/06
                                                                153016          4290AC153016
                                                                44 55 08.0 087 35 37.0
                                                                GREEN BAY OPEN WATER DNR STA 43
                                                                55      WISCONSIN
                                                                LAKE MICHIGAN

                                                                21WIS                  2111202
                                                                2                      0065 FEET  DEPTH

                          00671     00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH PHOS-DIS  PHOS-TOT   ORG N      NO3-N      NO2-N      NH3-N     CHLRPHYL   PHEOPHTN
  FROM     OF         ORTHO                 N         DISS       DISS       TOTAL     A UG/L        A
   TO     DAY  FEET   MG/L P    MG/L P     MG/L       MG/L       MG/L       MG/L     CORRECTD     UG/L

73/09/24       0007    0.003     0.011     0.100       0.01      0.002      0.046       6.00       1.00
74/05/21       0007              0.013     0.100       0.27      0.017      0.230       3.80
74/05/21       0059    0.012     0.016     0.400       0.46      0.018      0.160
74/06/04       0007    0.002     0.060     0.100K      0.01K     0.006      0.120       6.60       1.60
74/07/08       0007    0.012     0.032     0.700       0.03      0.077      0.050      11.70
74/08/13       0007    0.003     0.031     0.200       0.11      0.001K     0.010K      4.10       4.70
74/09/05       0007    0.003     0.025     0.100K      0.19      0.011      0.070
```

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STORET RETRIEVAL DATE 75/06/06
                                                                  153017         42VUAC153017
                                                                  44 53 02.0 087 32 13.0
                                                                  GREEN BAY OPEN WATER UWM STA 44
                                                                  55      WISCONSIN
                                                                  LAKE MICHIGAN

                                                                  21-15                  2111202
                                                                  2                     0065 FEET  DEPTH

                          72028     72029      00010      00299      00077      00310      00312      00940      00530
  DATE    TIME DEPTH   AZIMUTH  DISTANCE     WATER        DO       TRANSP      BOD        BOD      CHLORIDE   RESIDUE
  FROM     OF          FR SOUTH FR SOUTH      TEMP      PROBE      SECCHI     5 DAY      6 DAY        CL      TOT NFLT
   TO     DAY  FEET    DEGREES    FEET        CENT       MG/L      METERS      MG/L       MG/L       MG/L       MG/L

73/09/24       0003                           14.0        9.2        2.1
73/09/24       0007                                                                                               1
73/09/24       0010                           14.0        9.1
73/09/24       0020                           14.0        9.0
73/09/24       0030                           14.0        8.8
73/09/24       0039                           14.0        8.7
74/05/21       0003                            8.5       12.2        2.1
74/05/21       0013                            7.0       12.3
74/05/21       0030                            6.5       12.0
74/05/21       0043                            6.0       12.4
74/06/04       0003                           13.0       11.1        1.8
74/06/04       0010                           12.0       11.1
74/06/04       0020                           12.0       11.2
74/06/04       0030                           11.5       11.2
74/06/04       0043                           11.5       11.0
74/07/08       0003                           21.0        9.0        2.4
74/07/08       0023                           19.0        8.6
74/07/08       0046                           11.0        7.9
74/08/13       0003                           19.5        9.1        2.3
74/08/13       0016                           18.0        8.4
74/08/13       0033                           18.0        7.9
74/08/13       0046                           18.0        7.8
74/09/05       0003                           18.0       10.0        1.8
74/09/05       0023                           17.0        9.4
74/09/05       0043                           16.0        8.0
74/09/05       0049                           13.0        7.6

                                                                  153017         42VUAC153017
                                                                  44 53 02.0 087 32 13.0
                                                                  GREEN BAY OPEN WATER UWM STA 44
                                                                  55      WISCONSIN
                                                                  LAKE MICHIGAN

                                                                  21-15                  2111202
                                                                  2                     0065 FEET  DEPTH

                      00671      00665      00605      00618      00613      00610      32211      32218
  DATE    TIME DEPTH PHOS-DIS   PHOS-TOT    ORG N      NO3-N      NO2-N      NH3-N    CHLRPHYL   PHEOPHTN
  FROM     OF         ORTHO                   N         DISS       DISS      TOTAL     A UG/L        A
   TO     DAY  FEET   MG/L P     MG/L P      MG/L       MG/L       MG/L       MG/L    CORRECTD      UG/L

73/09/24       0007   0.002      0.012      0.100      0.03      0.001      0.000       5.00       3.00
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STORET RETRIEVAL DATE 75/06/06
                                                                      153010          4290AC153010
                                                                     44 53 44.0 087 25 06.0
                                                                     GREEN BAY OPEN WATER DNR STA 45
                                                                     55      WISCONSIN
                                                                     LAKE MICHIGAN

                                                                     21615                  2111202
                                                                     2                      0045 FEET  DEPTH

                          72028     72029     00010     00299     00078     00310     00312     00940     00530
  DATE    TIME DEPTH    AZIMUTH  DISTANCE    WATER       DO      TRANSP     BOD       BOD     CHLORIDE  RESIDUE
  FROM     OF          FR SOUTH  FR SOUTH    TEMP      PROBE     SECCHI    5 DAY     6 DAY       CL     TOT NFLT
   TO     DAY  FEET    DEGREES     FEET      CENT      MG/L      METERS    MG/L      MG/L      MG/L      MG/L

73/09/24       0003                          19.0       9.4       2.1
73/09/24       0007                                                                                         1
73/09/24       0010                          19.0       9.4
73/09/24       0020                          19.0       9.3
73/09/24       0030                          19.0       9.2
74/06/04       0003                          12.0      11.6       2.3
74/06/04       0007                                                         3.3                  8        0.9
74/06/04       0010                          11.5      11.5
74/06/04       0020                          11.5      11.4
74/06/04       0030                          11.0      11.3
74/06/04       0045                          11.0      11.2                 2.9                  8        0.1
74/07/08       0003                          21.5       9.4       1.5
74/07/08       0007                                                                   4.3        7        0.9
74/07/08       0023                          20.0       8.5
74/07/08       0046                          13.0       7.5                           3.7        8          4
74/08/13       0003                          19.0       9.3       2.1
74/08/13       0007                                                         4.9                  8          3
74/08/13       0013                          18.5       8.9
74/08/13       0026                          18.0       8.2
74/08/13       0030                          15.5       7.4
74/08/13       0033                          13.0       5.7
74/08/13       0046                          12.0       5.7                 4.1                  6          4
74/09/05       0003                          18.0      10.1       1.6
74/09/05       0007                                                         3.3                  8          3
74/09/05       0025                          18.0       9.8
74/09/05       0049                          18.0       9.8                 3.3                  8          4
                                                                      153010          4290AC153010
                                                                     44 53 44.0 087 25 06.0
                                                                     GREEN BAY OPEN WATER DNR STA 45
                                                                     55      WISCONSIN
                                                                     LAKE MICHIGAN

                                                                     21615                  2111202
                                                                     2                      0045 FEET  DEPTH

                          00671     00665     00605     00618     00613     00610     32211     32218
  DATE    TIME DEPTH    PHOS-DIS  PHOS-TOT    ORG N    NO3-N     NO2-N     NH3-N    CHLRPHYL  PHEOPHTN
  FROM     OF            ORTHO                  N       DISS      DISS      TOTAL    A UG/L       A
   TO     DAY  FEET     MG/L P    MG/L P      MG/L      MG/L      MG/L      MG/L    CORRECTD    UG/L

73/09/24       0007      0.001     0.010     0.100      0.04     0.000     0.000      6.00      4.00
74/06/04       0007      0.003     0.080     0.100K     0.06     0.010     0.100      4.40      0.00
74/06/04       0045      0.003     0.080     0.100K     0.32     0.012     0.050
74/07/08       0007      0.006     0.040     0.400      0.02     0.020     0.000      5.30      0.20
74/07/08       0046      0.006     0.041     0.500      0.48     0.052     0.000
74/08/13       0007      0.012     0.014     0.300      0.04     0.001K    0.010K     0.00      4.40
74/08/13       0046      0.003     0.018     0.200      0.73     0.004     0.010K
74/09/05       0007      0.003     0.021     0.100K     0.02     0.006     0.050      3.30      2.50
74/09/05       0049      0.002     0.017     0.100K     0.30     0.011     0.050
```